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(54) **ORGANIC ELECTROLUMINESCENT MATERIALS AND DEVICES**

(71) Applicant: **Universal Display Corporation**, Ewing, NJ (US)

(72) Inventors: **Raymond Kwong**, Fo Tan (HK); **Chuanjun Xia**, Lawrenceville, NJ (US); **Scott Joseph**, Ewing, NJ (US); **Siu Tung Lam**, Apleichau (HK); **Chi Hang Lee**, Chaiwan (HK)

(73) Assignee: **Universal Display Corporation**, Ewing, NJ (US)

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C09K 11/06	(2006.01)

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CPC ***H01L 51/0061*** (2013.01); ***C09K 11/06*** (2013.01); ***H01L 51/0071*** (2013.01); ***H01L 51/0072*** (2013.01); ***H01L 51/0073*** (2013.01); ***H01L 51/0074*** (2013.01); *H01L 51/5016* (2013.01)

(58) **Field of Classification Search**

None

See application file for complete search history.

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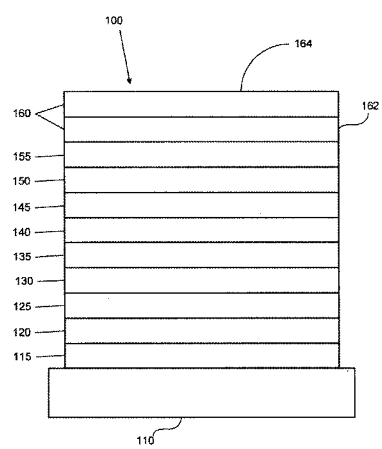
(57) **ABSTRACT**

Luminescent materials including donor-acceptor compounds with a high triplet energy heteropolyaromatic system, namely, dibenzofuran, dibenzothiophene and dibenzoselenophene with one or multiple nitrogens in the ring as the electron acceptor for use as emitters in organic light emitting diodes is disclosed.

23 Claims, 3 Drawing Sheets



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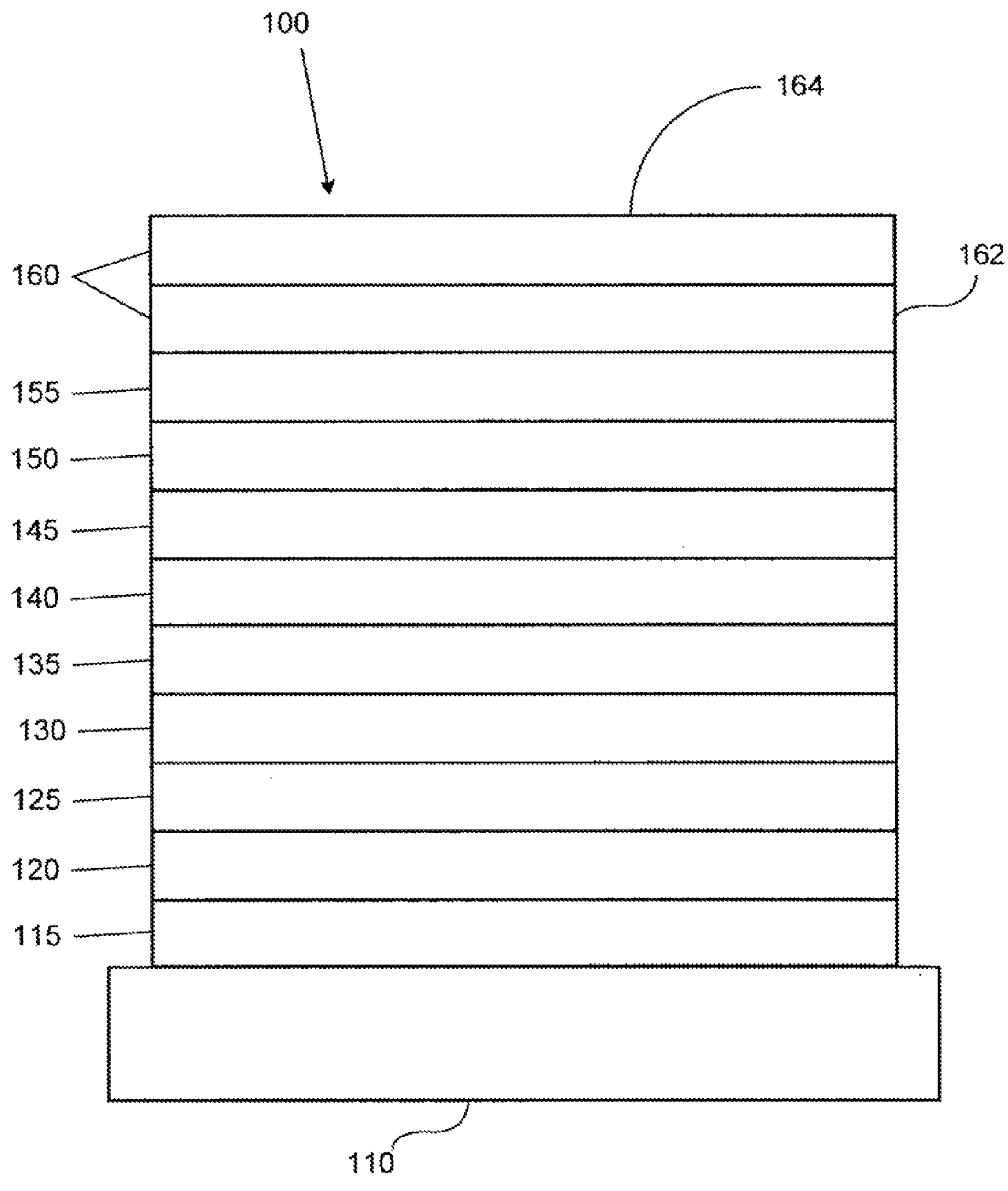


FIG. 1

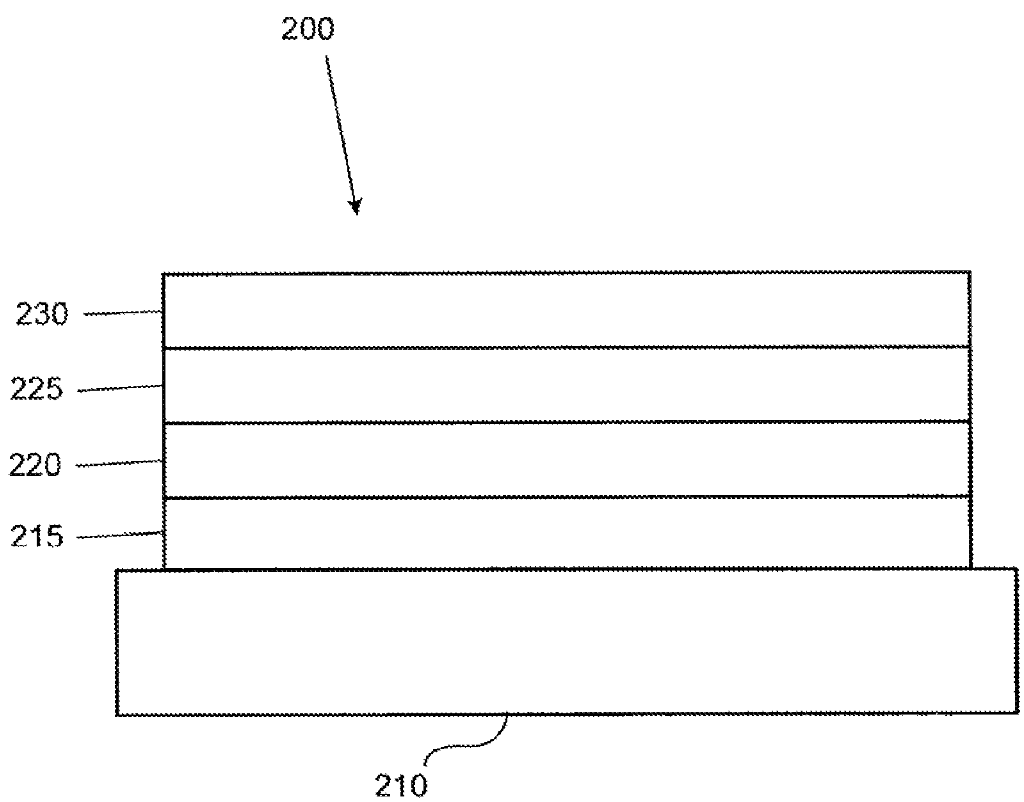
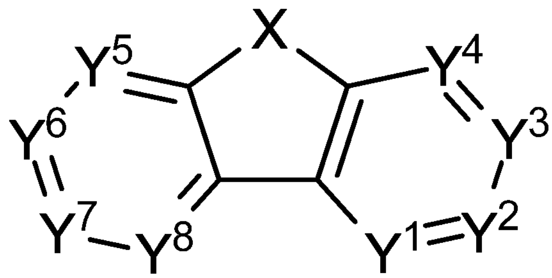


FIG. 2



Formula I

FIG. 3

ORGANIC ELECTROLUMINESCENT MATERIALS AND DEVICES

PARTIES TO A JOINT RESEARCH AGREEMENT

The claimed invention was made by, on behalf of, and/or in connection with one or more of the following parties to a joint university corporation research agreement: Regents of the University of Michigan, Princeton University, University of Southern California, and the Universal Display Corporation. The agreement was in effect on and before the date the claimed invention was made, and the claimed invention was made as a result of activities undertaken within the scope of the agreement.

FIELD OF THE INVENTION

The present invention relates to organic light emitting devices. More specifically, the present disclosure pertains to luminescent materials comprising donor-acceptor compounds with a high triplet energy heteropolyaromatic system as the electron acceptor for use as emitters in organic light emitting diodes.

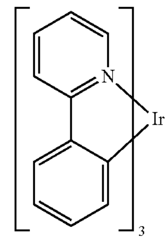
BACKGROUND

Opto-electronic devices that make use of organic materials are becoming increasingly desirable for a number of reasons. Many of the materials used to make such devices are relatively inexpensive, so organic opto-electronic devices have the potential for cost advantages over inorganic devices. In addition, the inherent properties of organic materials, such as their flexibility, may make them well suited for particular applications such as fabrication on a flexible substrate. Examples of organic opto-electronic devices include organic light emitting devices (OLEDs), organic phototransistors, organic photovoltaic cells, and organic photodetectors. For OLEDs, the organic materials may have performance advantages over conventional materials. For example, the wavelength at which an organic emissive layer emits light may generally be readily tuned with appropriate dopants.

OLEDs make use of thin organic films that emit light when voltage is applied across the device. OLEDs are becoming an increasingly interesting technology for use in applications such as flat panel displays, illumination, and backlighting. Several OLED materials and configurations are described in U.S. Pat. Nos. 5,844,363, 6,303,238, and 5,707,745, which are incorporated herein by reference in their entirety.

One application for phosphorescent emissive molecules is a full color display. Industry standards for such a display call for pixels adapted to emit particular colors, referred to as "saturated" colors. In particular, these standards call for saturated red, green, and blue pixels. Color may be measured using CIE coordinates, which are well known to the art.

One example of a green emissive molecule is tris(2-phenylpyridine) iridium, denoted $Ir(ppy)_3$, which has the following structure:



In this, and later figures herein, we depict the dative bond from nitrogen to metal (here, Ir) as a straight line.

As used herein, the term "organic" includes polymeric materials as well as small molecule organic materials that may be used to fabricate organic opto-electronic devices. "Small molecule" refers to any organic material that is not a polymer, and "small molecules" may actually be quite large. Small molecules may include repeat units in some circumstances. For example, using a long chain alkyl group as a substituent does not remove a molecule from the "small molecule" class. Small molecules may also be incorporated into polymers, for example as a pendent group on a polymer backbone or as a part of the backbone. Small molecules may also serve as the core moiety of a dendrimer, which consists of a series of chemical shells built on the core moiety. The core moiety of a dendrimer may be a fluorescent or phosphorescent small molecule emitter. A dendrimer may be a "small molecule," and it is believed that all dendrimers currently used in the field of OLEDs are small molecules.

As used herein, "top" means furthest away from the substrate, while "bottom" means closest to the substrate. Where a first layer is described as "disposed over" a second layer, the first layer is disposed further away from substrate. There may be other layers between the first and second layer, unless it is specified that the first layer is "in contact with" the second layer. For example, a cathode may be described as "disposed over" an anode, even though there are various organic layers in between.

As used herein, "solution processible" means capable of being dissolved, dispersed, or transported in and/or deposited from a liquid medium, either in solution or suspension form.

A ligand may be referred to as "photoactive" when it is believed that the ligand directly contributes to the photoactive properties of an emissive material. A ligand may be referred to as "ancillary" when it is believed that the ligand does not contribute to the photoactive properties of an emissive material, although an ancillary ligand may alter the properties of a photoactive ligand.

As used herein, and as would be generally understood by one skilled in the art, a first "Highest Occupied Molecular Orbital" (HOMO) or "Lowest Unoccupied Molecular Orbital" (LUMO) energy level is "greater than" or "higher than" a second HOMO or LUMO energy level if the first energy level is closer to the vacuum energy level. Since ionization potentials (IP) are measured as a negative energy relative to a vacuum level, a higher HOMO energy level corresponds to an IP having a smaller absolute value (an IP that is less negative). Similarly, a higher LUMO energy level corresponds to an electron affinity (EA) having a smaller absolute value (an EA that is less negative). On a conventional energy level diagram, with the vacuum level at the top, the LUMO energy level of a material is higher than the HOMO energy level of the same material. A "higher" HOMO or LUMO energy level appears closer to the top of such a diagram than a "lower" HOMO or LUMO energy level.

As used herein, and as would be generally understood by one skilled in the art, a first work function is "greater than" or "higher than" a second work function if the first work function has a higher absolute value. Because work functions are generally measured as negative numbers relative to vacuum level, this means that a "higher" work function is more negative. On a conventional energy level diagram, with the vacuum level at the top, a "higher" work function is illustrated as further away from the vacuum level in the downward direction. Thus, the definitions of HOMO and LUMO energy levels follow a different convention than work functions.

As used herein, the phrase "electron acceptor" means a fragment that can accept electron density from an aromatic system, and the phrase "electron donor" means a fragment that donates electron density into an aromatic system.

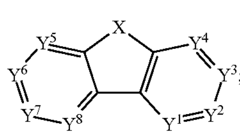
More details on OLEDs, and the definitions described above, can be found in U.S. Pat. No. 7,279,704, which is incorporated herein by reference in its entirety.

SUMMARY OF THE INVENTION

Donor-acceptor compounds with nitrogen containing dibenzofuran, dibenzothiophene and dibenzoselenophene as the acceptor may be efficient emitters with emission originated from the charge transfer (CT) state. The emission can be tuned by varying the strength of the donor-acceptor interaction and the resulting energy of the CT state. The compounds may be used as emitters in OLED.

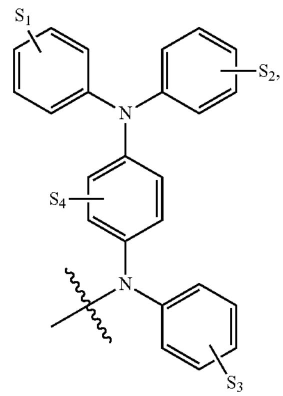
According to an embodiment, a compound having the formula:

Formula 1

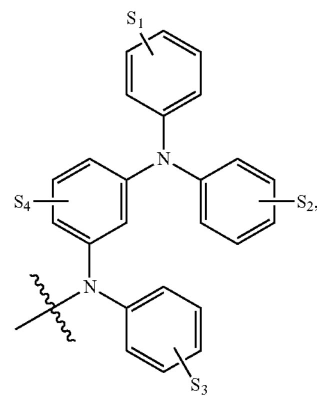


wherein each of Y^1 to Y^8 is C—R or N; at least two of Y^1 to Y^8 are N; at least one of Y^1 to Y^8 is C—R; each R is independently selected from the group consisting of hydrogen, deuterium, halide, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrile, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof; wherein at least one of the R is selected from the group of substituents consisting of D1 through D140 shown below,

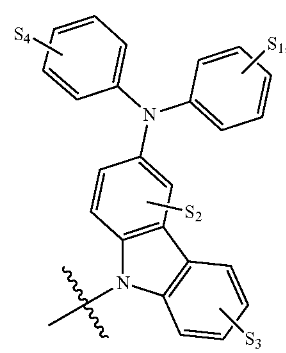
D1



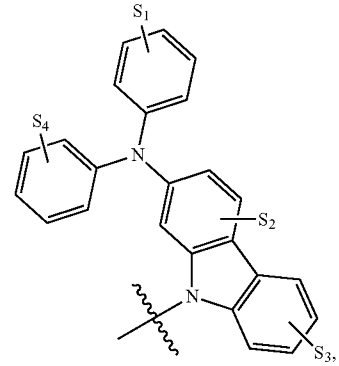
D2



D3



D4



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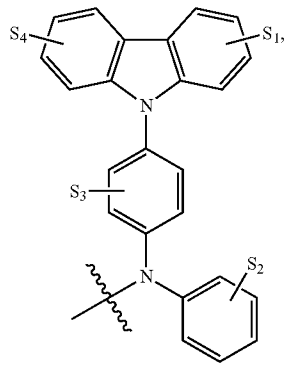
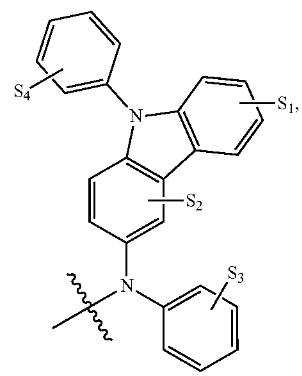


D5



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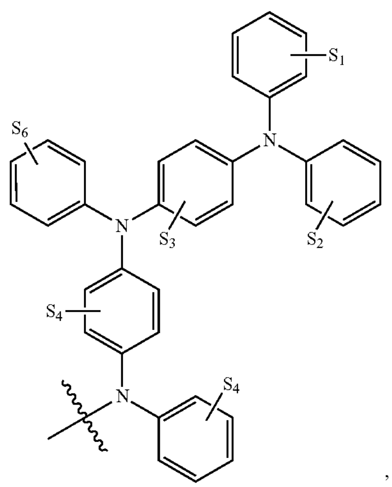

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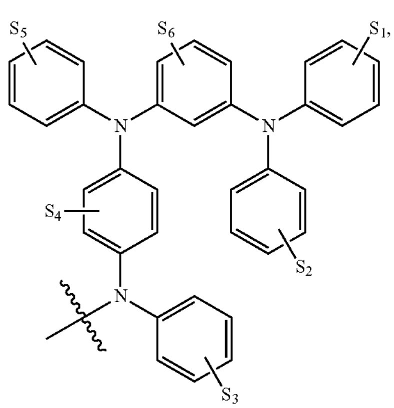

D8

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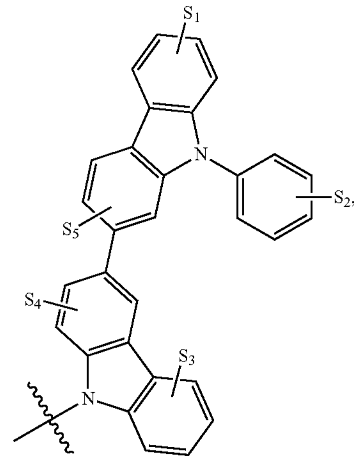
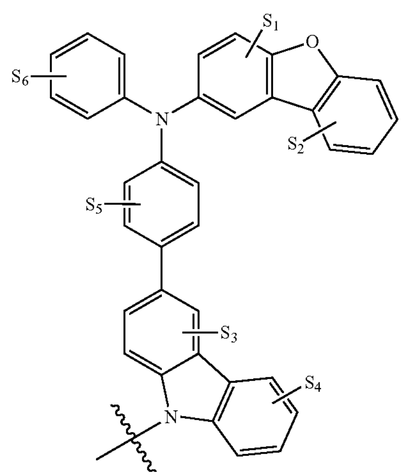


D9



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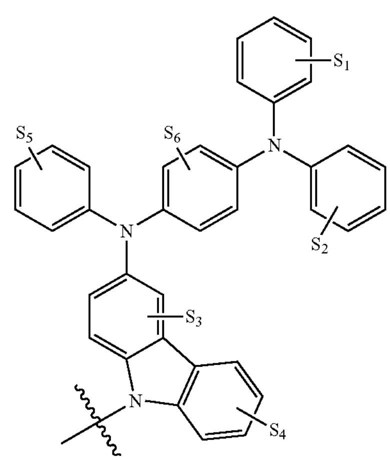

D11

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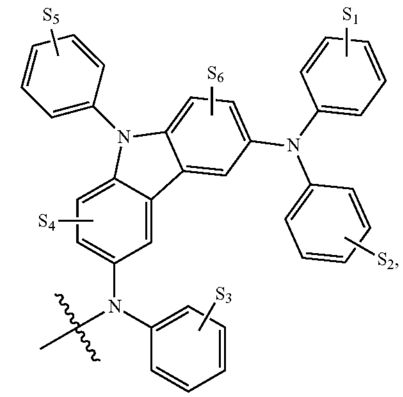

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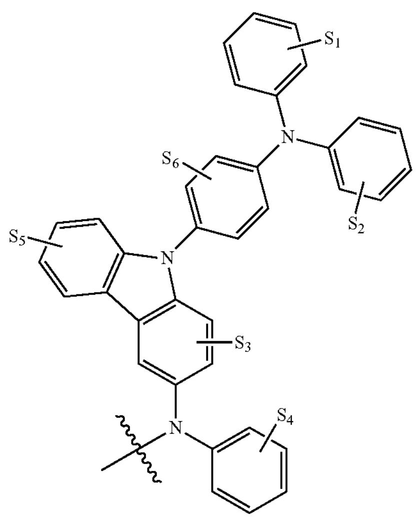

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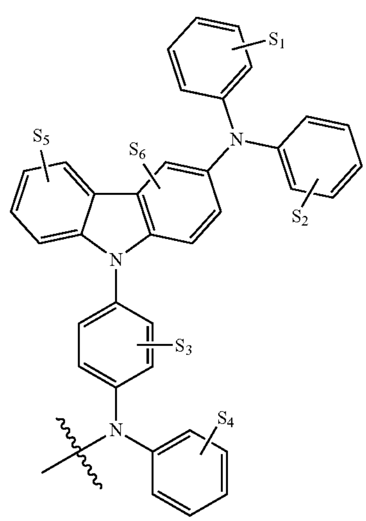

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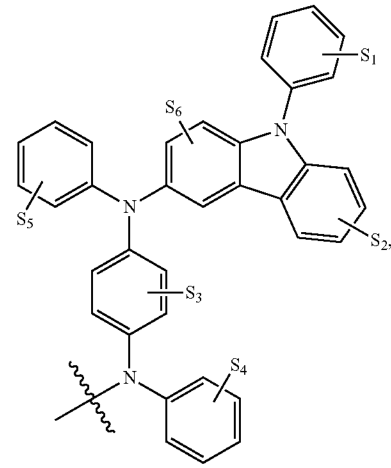

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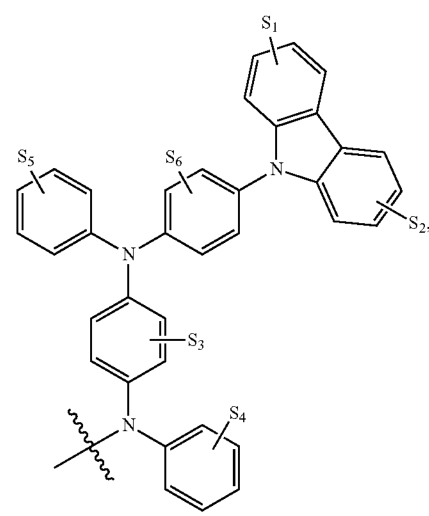

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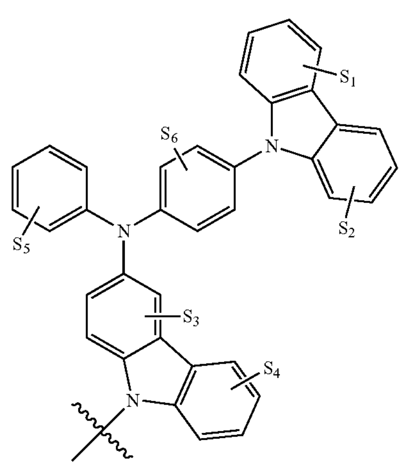

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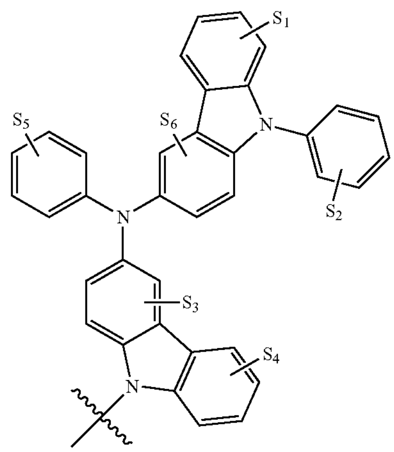

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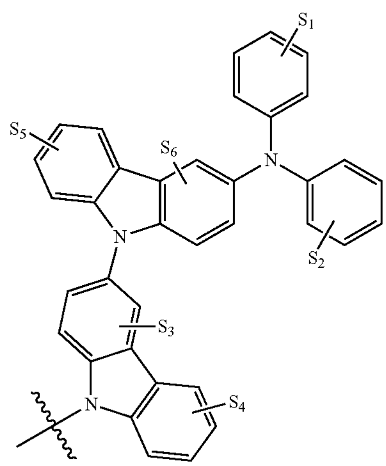
D19



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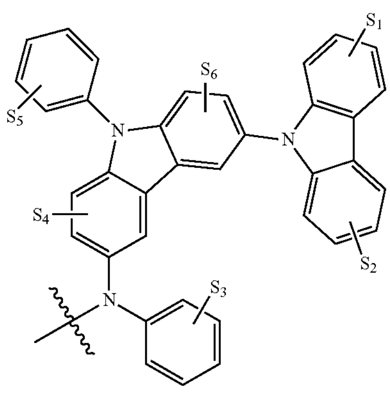
D20



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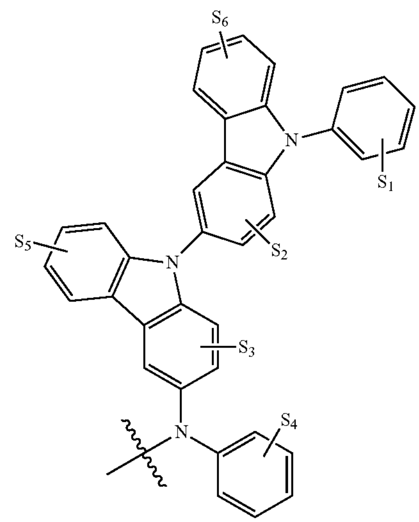
D21



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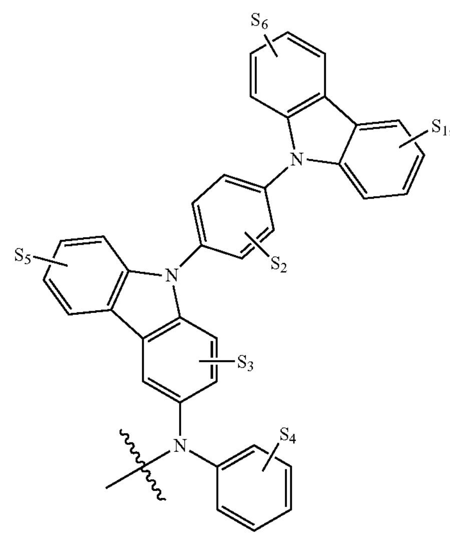
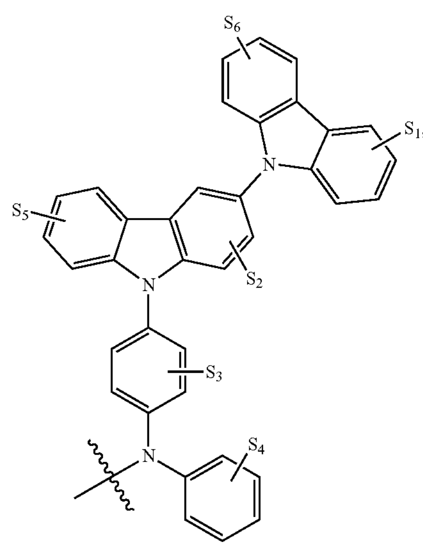
D22



D23



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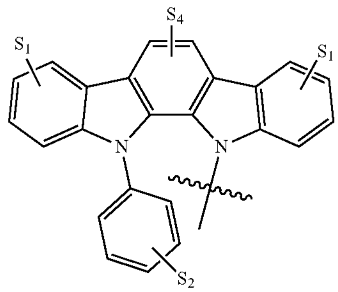

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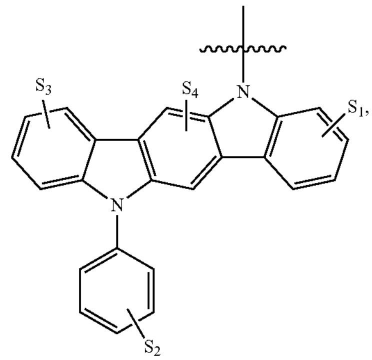

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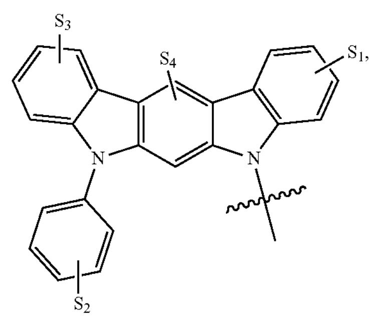

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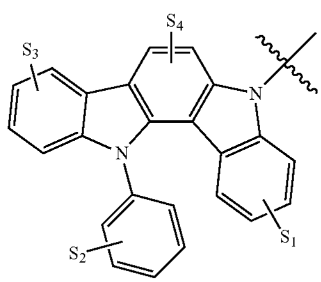

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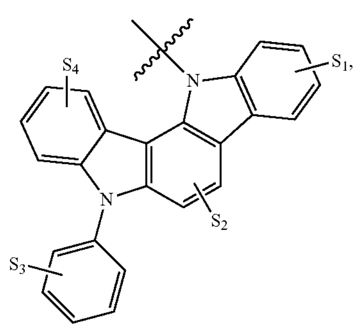

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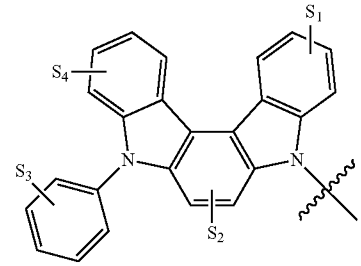
D29



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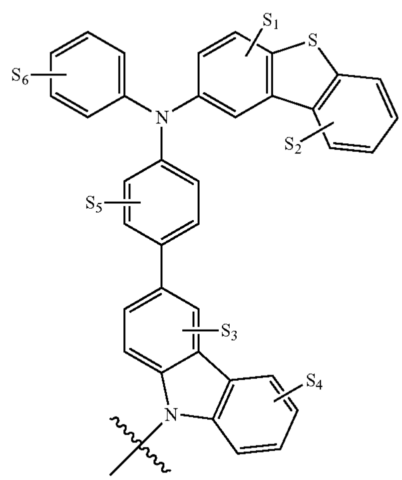
D30



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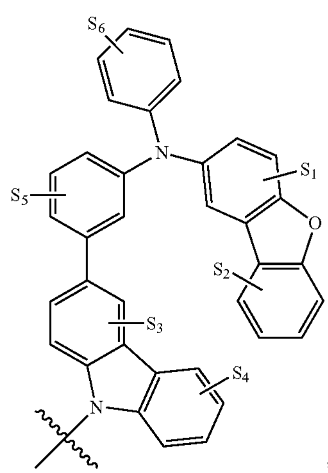
D31



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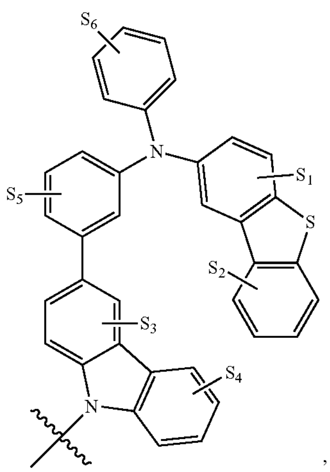

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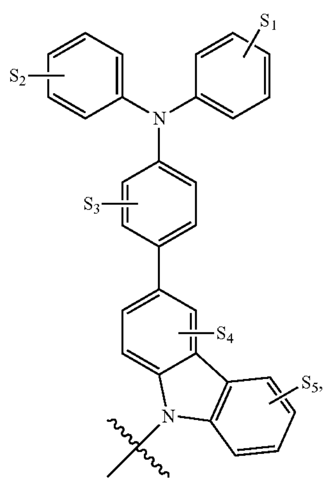
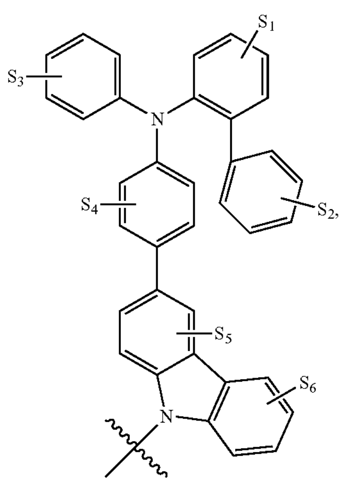


D34



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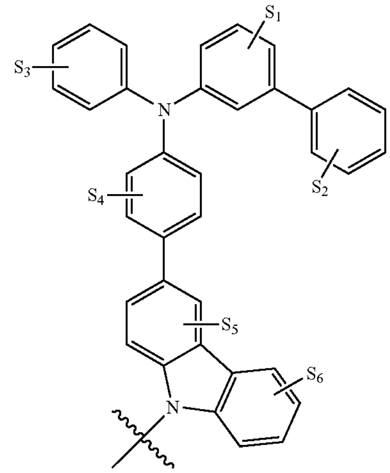
D35



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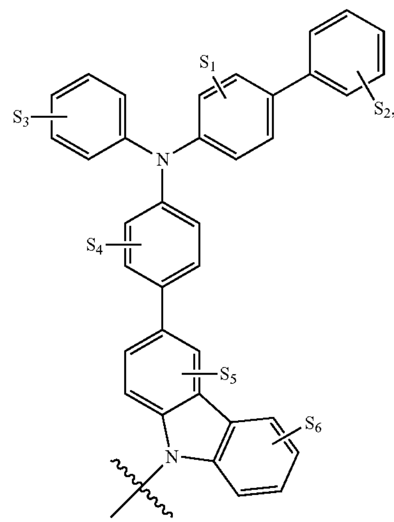
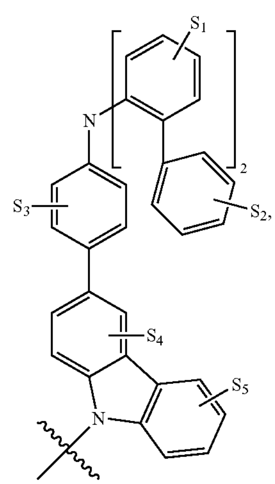
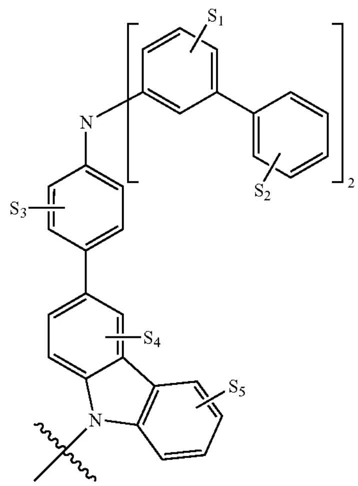
D36



D37





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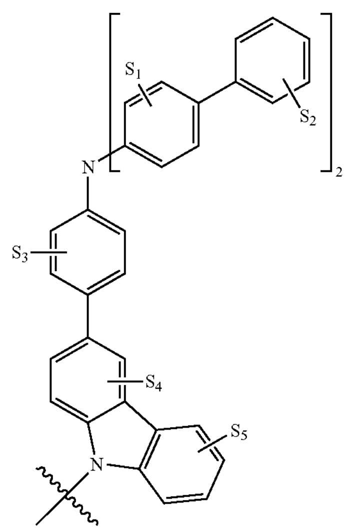

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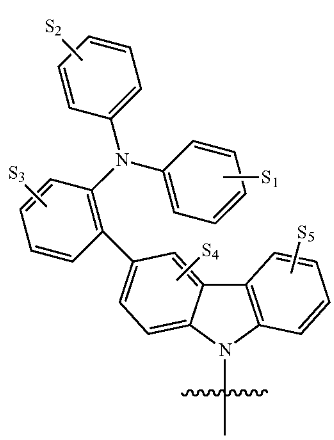

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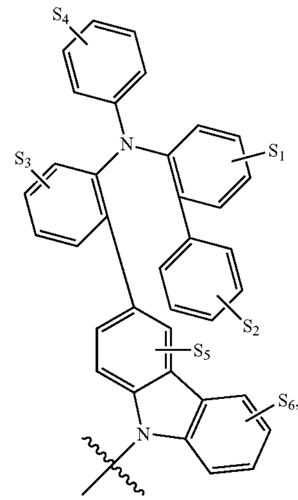
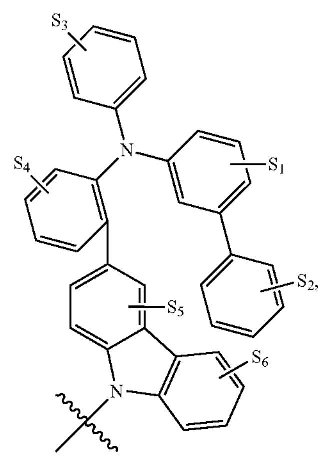
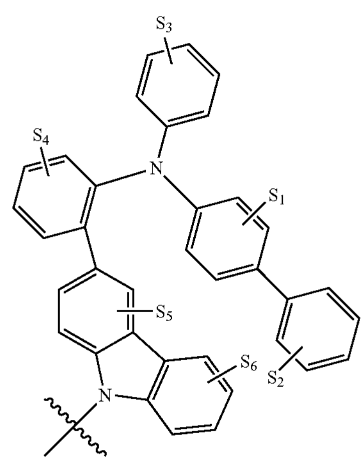


D41



D42



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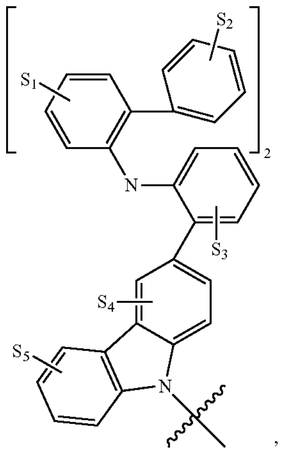
D44



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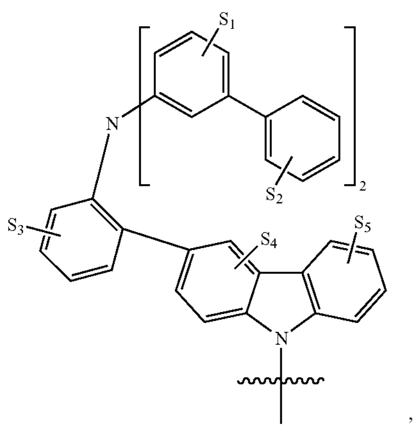

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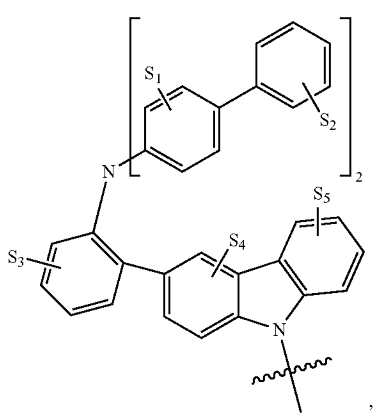

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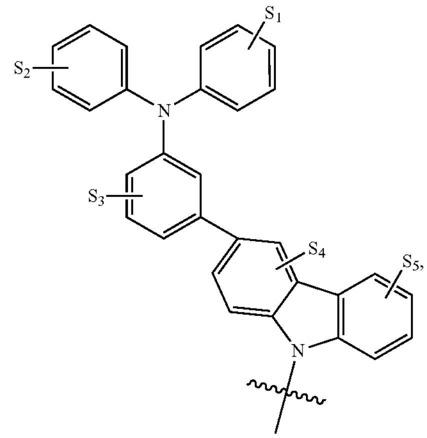
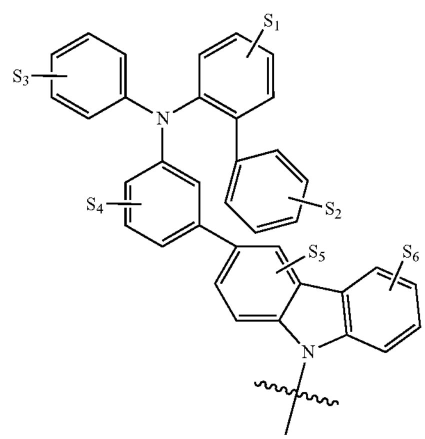
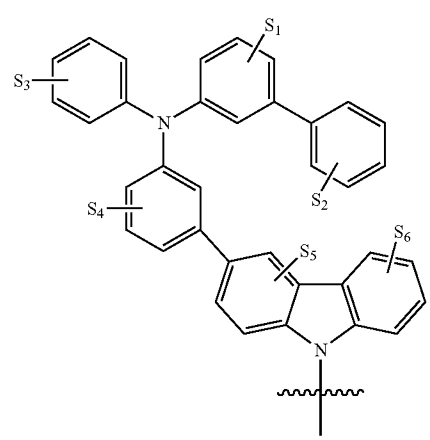
D47



D48



D49



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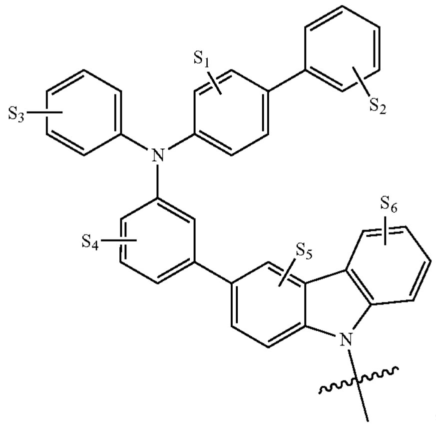
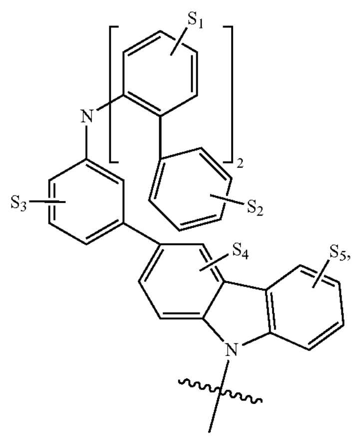
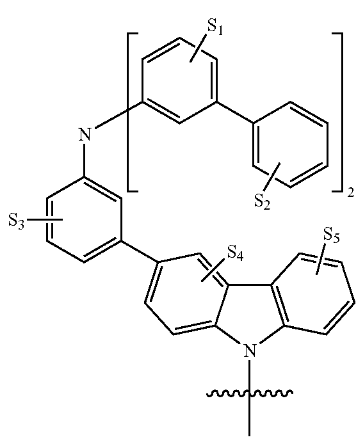
D50



D51



D52



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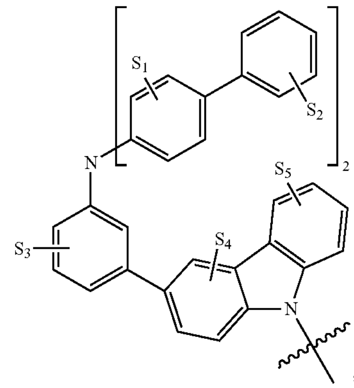
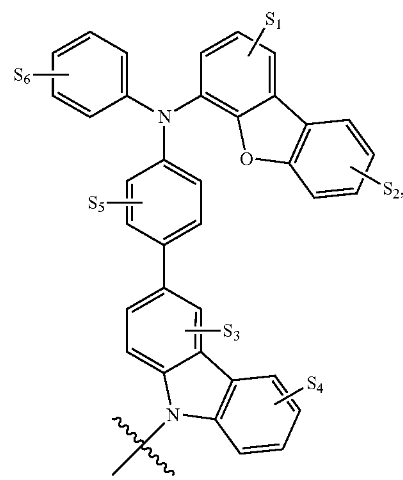
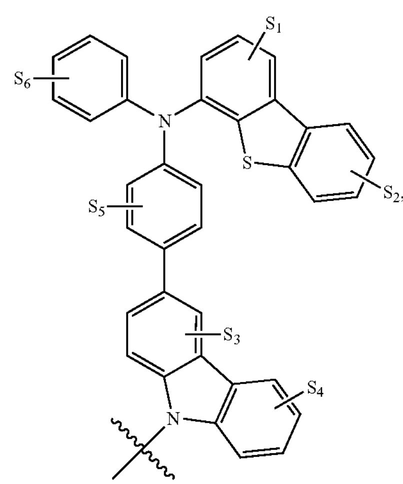
D53



D54



D55



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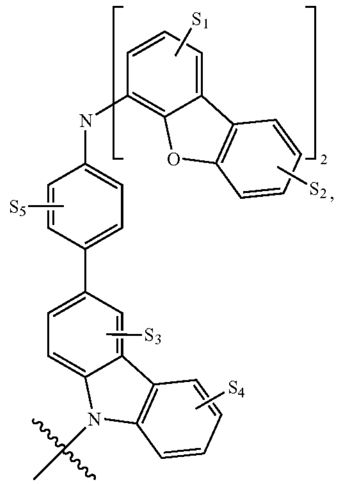
D56



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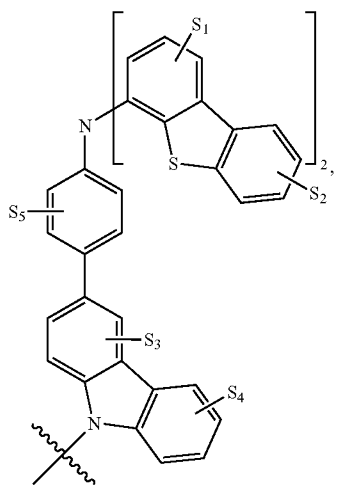

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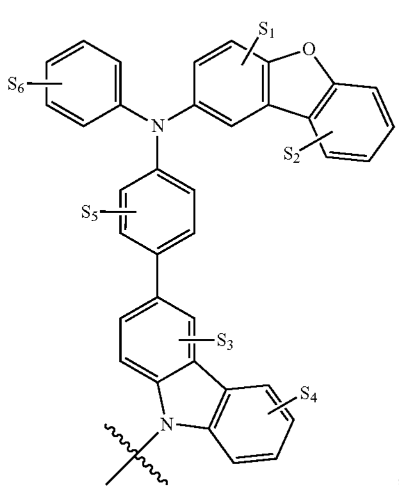

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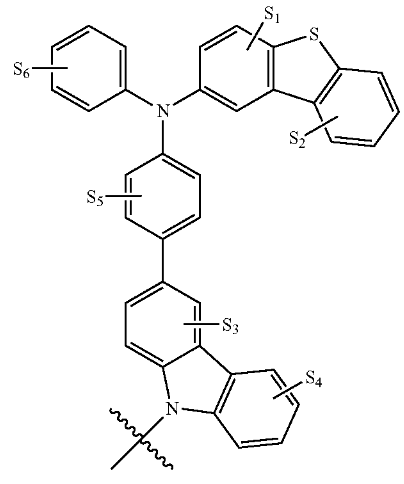
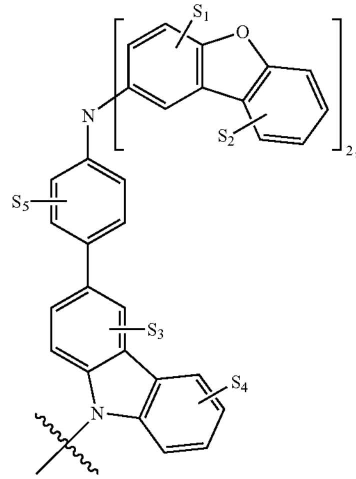
D59



D60



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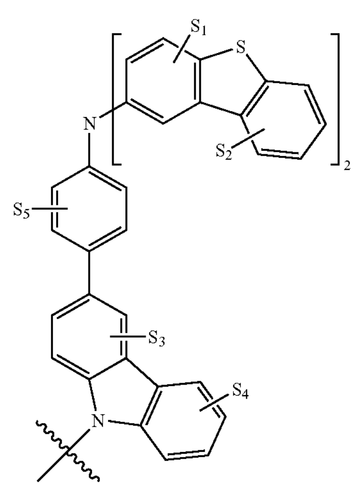

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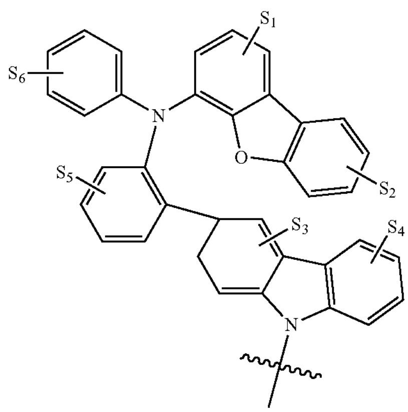
D62



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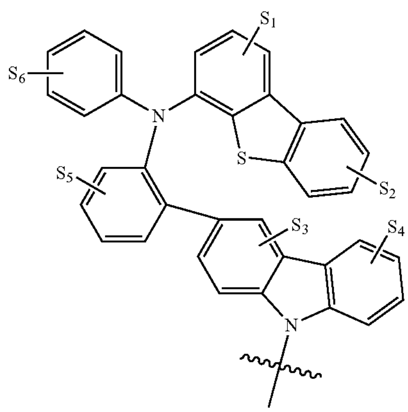
D63



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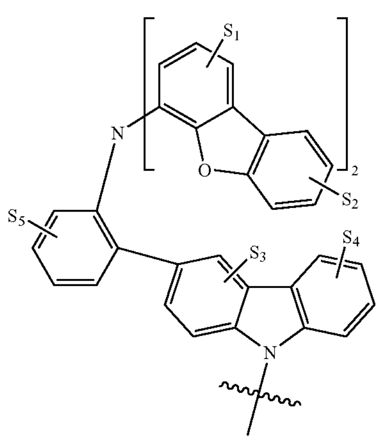

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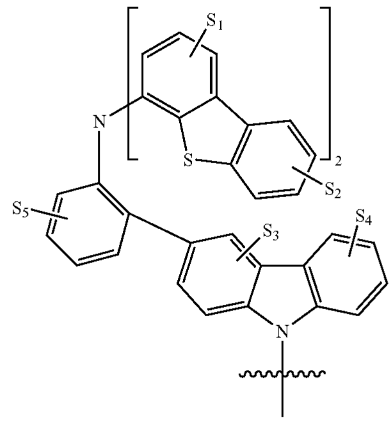
D65



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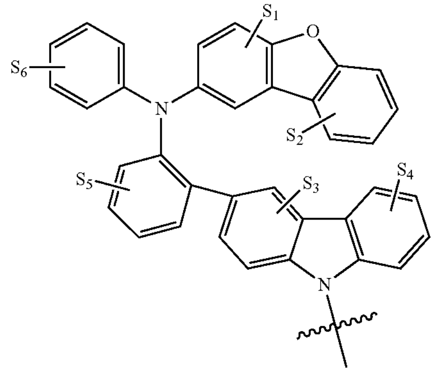
D66



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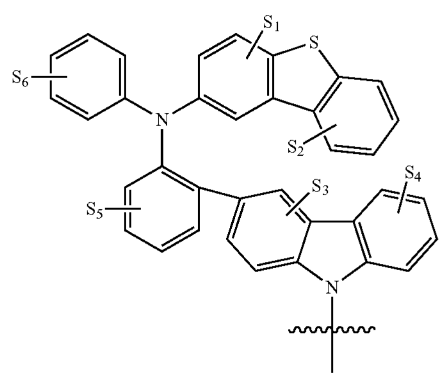
D67



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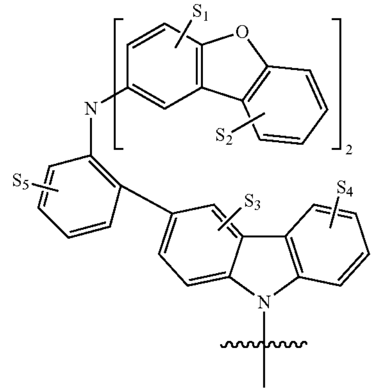
D68



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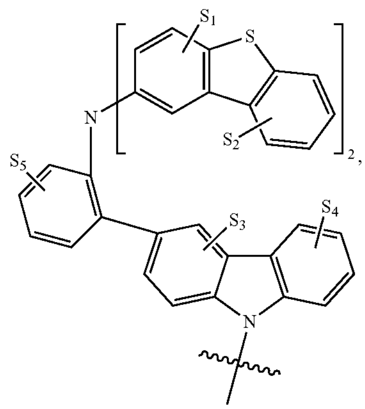
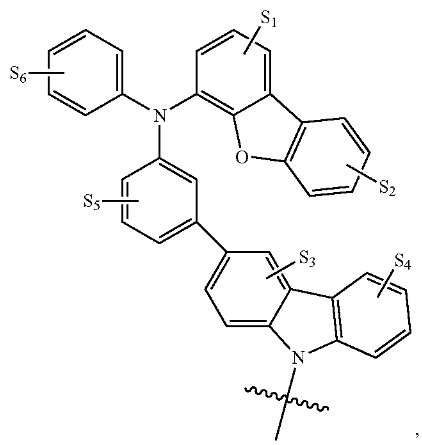
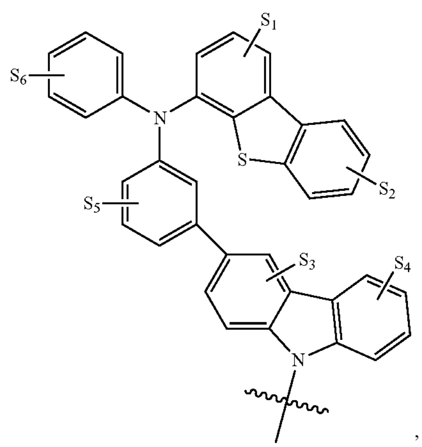
D69



D70



D71



wherein S_1 to S_7 represent mono, di, tri, tetra or penta substitutions with hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrile, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof.

According to another aspect of the present disclosure, a first device comprising a first organic light emitting device is also provided. The first organic light emitting device can include an anode, a cathode, and an organic emissive layer disposed between the anode and the cathode. The organic emissive layer can include a compound of Formula 1, wherein each of Y^1 to Y^8 is C—R or N; at least one of Y^1 to Y^8 is N; at least one of Y^1 to Y^8 is C—R; each R is independently selected

from the group consisting of hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrile, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof; wherein at least one of the R comprises a donor group with at least one electron-donating nitrogen.

The first device can be a consumer product, an organic light-emitting device, and/or a lighting panel.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** shows an organic light emitting device.

FIG. **2** shows an inverted organic light emitting device that does not have a separate electron transport layer.

FIG. **3** shows Formula 1 as disclosed herein.

DETAILED DESCRIPTION

Generally, an OLED comprises at least one organic layer disposed between and electrically connected to an anode and a cathode. When a current is applied, the anode injects holes and the cathode injects electrons into the organic layer(s). The injected holes and electrons each migrate toward the oppositely charged electrode. When an electron and hole localize on the same molecule, an "exciton," which is a localized electron-hole pair having an excited energy state, is formed. Light is emitted when the exciton relaxes via a photoemissive mechanism. In some cases, the exciton may be localized on an excimer or an exciplex. Non-radiative mechanisms, such as thermal relaxation, may also occur, but are generally considered undesirable.

The initial OLEDs used emissive molecules that emitted light from their singlet states ("fluorescence") as disclosed, for example, in U.S. Pat. No. 4,769,292, which is incorporated by reference in its entirety. Fluorescent emission generally occurs in a time frame of less than 10 nanoseconds.

More recently, OLEDs having emissive materials that emit light from triplet states ("phosphorescence") have been demonstrated. Baldo et al., "Highly Efficient Phosphorescent Emission from Organic Electroluminescent Devices," Nature, vol. 395, 151-154, 1998; ("Baldo-I") and Baldo et al., "Very high-efficiency green organic light-emitting devices based on electrophosphorescence," Appl. Phys. Lett., vol. 75, No. 3, 4-6 (1999) ("Baldo-II"), which are incorporated by reference in their entireties. Phosphorescence is described in more detail in U.S. Pat. No. 7,279,704 at cols. 5-6, which are incorporated by reference.

FIG. **1** shows an organic light emitting device **100**. The figures are not necessarily drawn to scale. Device **100** may include a substrate **110**, an anode **115**, a hole injection layer **120**, a hole transport layer **125**, an electron blocking layer **130**, an emissive layer **135**, a hole blocking layer **140**, an electron transport layer **145**, an electron injection layer **150**, a protective layer **155**, a cathode **160**, and a barrier layer **170**. Cathode **160** is a compound cathode having a first conductive layer **162** and a second conductive layer **164**. Device **100** may be fabricated by depositing the layers described, in order. The properties and functions of these various layers, as well as example materials, are described in more detail in U.S. Pat. No. 7,279,704 at cols. 6-10, which are incorporated by reference.

More examples for each of these layers are available. For example, a flexible and transparent substrate-anode combination is disclosed in U.S. Pat. No. 5,844,363, which is incorporated by reference in its entirety. An example of a p-doped hole transport layer is m-MTDATA doped with F_4-TCNQ at a molar ratio of 50:1, as disclosed in U.S. Patent Application Publication No. 2003/0230980, which is incorporated by reference in its entirety. Examples of emissive and host materials are disclosed in U.S. Pat. No. 6,303,238 to Thompson et al., which is incorporated by reference in its entirety. An example of an n-doped electron transport layer is BPhen doped with Li at a molar ratio of 1:1, as disclosed in U.S. Patent Application Publication No. 2003/0230980, which is incorporated by reference in its entirety. U.S. Pat. Nos. 5,703,436 and 5,707,745, which are incorporated by reference in their entireties, disclose examples of cathodes including compound cathodes having a thin layer of metal such as Mg:Ag with an overlying transparent, electrically-conductive, sputter-deposited ITO layer. The theory and use of blocking layers is described in more detail in U.S. Pat. No. 6,097,147 and U.S. Patent Application Publication No. 2003/0230980, which are incorporated by reference in their entireties. Examples of injection layers are provided in U.S. Patent Application Publication No. 2004/0174116, which is incorporated by reference in its entirety. A description of protective layers may be found in U.S. Patent Application Publication No. 2004/0174116, which is incorporated by reference in its entirety.

FIG. **2** shows an inverted OLED **200**. The device includes a substrate **210**, a cathode **215**, an emissive layer **220**, a hole transport layer **225**, and an anode **230**. Device **200** may be fabricated by depositing the layers described, in order. Because the most common OLED configuration has a cathode disposed over the anode, and device **200** has cathode **215** disposed under anode **230**, device **200** may be referred to as an "inverted" OLED. Materials similar to those described with respect to device **100** may be used in the corresponding layers of device **200**. FIG. **2** provides one example of how some layers may be omitted from the structure of device **100**.

The simple layered structure illustrated in FIGS. **1** and **2** is provided by way of non-limiting example, and it is understood that embodiments of the invention may be used in connection with a wide variety of other structures. The specific materials and structures described are exemplary in nature, and other materials and structures may be used. Functional OLEDs may be achieved by combining the various layers described in different ways, or layers may be omitted entirely, based on design, performance, and cost factors. Other layers not specifically described may also be included. Materials other than those specifically described may be used. Although many of the examples provided herein describe various layers as comprising a single material, it is understood that combinations of materials, such as a mixture of host and dopant, or more generally a mixture, may be used. Also, the layers may have various sublayers. The names given to the various layers herein are not intended to be strictly limiting. For example, in device **200**, hole transport layer **225** transports holes and injects holes into emissive layer **220**, and may be described as a hole transport layer or a hole injection layer. In one embodiment, an OLED may be described as having an "organic layer" disposed between a cathode and an anode. This organic layer may comprise a single layer, or may further comprise multiple layers of different organic materials as described, for example, with respect to FIGS. **1** and **2**.

Structures and materials not specifically described may also be used, such as OLEDs comprised of polymeric materials (PLEDs) such as disclosed in U.S. Pat. No. 5,247,190 to Friend et al., which is incorporated by reference in its entirety. By way of further example, OLEDs having a single organic layer may be used. OLEDs may be stacked, for example as described in U.S. Pat. No. 5,707,745 to Forrest et al, which is incorporated by reference in its entirety. The OLED structure may deviate from the simple layered structure illustrated in FIGS. **1** and **2**. For example, the substrate may include an angled reflective surface to improve out-coupling, such as a mesa structure as described in U.S. Pat. No. 6,091,195 to Forrest et al., and/or a pit structure as described in U.S. Pat. No. 5,834,893 to Bulovic et al., which are incorporated by reference in their entireties.

Unless otherwise specified, any of the layers of the various embodiments may be deposited by any suitable method. For the organic layers, preferred methods include thermal evaporation, ink-jet, such as described in U.S. Pat. Nos. 6,013,982 and 6,087,196, which are incorporated by reference in their entireties, organic vapor phase deposition (OVPD), such as described in U.S. Pat. No. 6,337,102 to Forrest et al., which is incorporated by reference in its entirety, and deposition by organic vapor jet printing (OVJP), such as described in U.S. Pat. No. 7,431,968, which is incorporated by reference in its entirety. Other suitable deposition methods include spin coating and other solution based processes. Solution based processes are preferably carried out in nitrogen or an inert atmosphere. For the other layers, preferred methods include thermal evaporation. Preferred patterning methods include deposition through a mask, cold welding such as described in U.S. Pat. Nos. 6,294,398 and 6,468,819, which are incorporated by reference in their entireties, and patterning associated with some of the deposition methods such as ink jet and OVJD. Other methods may also be used. The materials to be deposited may be modified to make them compatible with a particular deposition method. For example, substituents such as alkyl and aryl groups, branched or unbranched, and preferably containing at least 3 carbons, may be used in small molecules to enhance their ability to undergo solution processing. Substituents having 20 carbons or more may be used, and 3-20 carbons is a preferred range. Materials with asymmetric structures may have better solution processibility than those having symmetric structures, because asymmetric materials may have a lower tendency to recrystallize. Dendrimer substituents may be used to enhance the ability of small molecules to undergo solution processing.

Devices fabricated in accordance with embodiments of the present invention may further optionally comprise a barrier layer. One purpose of the barrier layer is to protect the electrodes and organic layers from damaging exposure to harmful species in the environment including moisture, vapor and/or gases, etc. The barrier layer may be deposited over, under or next to a substrate, an electrode, or over any other parts of a device including an edge. The barrier layer may comprise a single layer, or multiple layers. The barrier layer may be formed by various known chemical vapor deposition techniques and may include compositions having a single phase as well as compositions having multiple phases. Any suitable material or combination of materials may be used for the barrier layer. The barrier layer may incorporate an inorganic or an organic compound or both. The preferred barrier layer comprises a mixture of a polymeric material and a non-polymeric material as described in U.S. Pat. No. 7,968,146, PCT Pat. Application Nos. PCT/US2007/023098 and PCT/US2009/042829, which are herein incorporated by reference in their entireties. To be considered a "mixture", the aforesaid polymeric and non-polymeric materials comprising the barrier layer should be deposited under the same reaction conditions and/or at the same time. The weight ratio of polymeric to non-polymeric material may be in the range of 95:5 to 5:95. The polymeric material and the non-polymeric material may be created from the same precursor material. In one example, the mixture of a polymeric material and a non-polymeric material consists essentially of polymeric silicon and inorganic silicon.

Devices fabricated in accordance with embodiments of the invention may be incorporated into a wide variety of consumer products, including flat panel displays, computer monitors, medical monitors, televisions, billboards, lights for interior or exterior illumination and/or signaling, heads up displays, fully transparent displays, flexible displays, laser printers, telephones, cell phones, personal digital assistants (PDAs), laptop computers, digital cameras, camcorders, viewfinders, micro-displays, 3-D displays, vehicles, a large area wall, theater or stadium screen, or a sign. Various control mechanisms may be used to control devices fabricated in accordance with the present invention, including passive matrix and active matrix. Many of the devices are intended for use in a temperature range comfortable to humans, such as 18 degrees C. to 30 degrees C., and more preferably at room temperature (20-25 degrees C.), but could be used outside this temperature range, for example, from −40 degree C. to +80 degree C.

The materials and structures described herein may have applications in devices other than OLEDs. For example, other optoelectronic devices such as organic solar cells and organic photodetectors may employ the materials and structures. More generally, organic devices, such as organic transistors, may employ the materials and structures.

The terms halo, halogen, alkyl, cycloalkyl, alkenyl, alkynyl, aralkyl, heterocyclic group, aryl, aromatic group, and heteroaryl are known to the art, and are defined in U.S. Pat. No. 7,279,704 at cols. 31-32, which are incorporated herein by reference. As used herein, "substituted" indicates that a substituent other than H is bonded to the relevant carbon.

It is believed that the internal quantum efficiency (IQE) of fluorescent OLEDs can exceed the 25% spin statistics limit through delayed fluorescence. As used herein, there are two types of delayed fluorescence, i.e. P-type delayed fluorescence and E-type delayed fluorescence. P-type delayed fluorescence is generated from triplet-triplet annihilation (TTA).

On the other hand, E-type delayed fluorescence does not rely on the collision of two triplets, but rather on the thermal population between the triplet states and the singlet excited states. Compounds that are capable of generating E-type delayed fluorescence are required to have very small singlet-triplet gaps. Thermal energy can activate the transition from the triplet state back to the singlet state. This type of delayed fluorescence is also known as thermally activated delayed fluorescence (TADF). A distinctive feature of TADF is that the delayed component increases as temperature rises due to the increased thermal energy. If the reverse intersystem crossing rate is fast enough to minimize the non-radiative decay from the triplet state, the fraction of back populated singlet excited states can potentially reach 75%. The total singlet fraction can be 100%, far exceeding the spin statistics limit for electrically generated excitons.

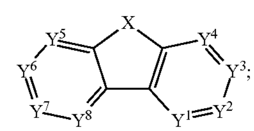
E-type delayed fluorescence characteristics can be found in an exciplex system or in a single compound. Without being bound by theory, it is believed that E-type delayed fluorescence requires the luminescent material to have a small singlet-triplet energy gap (ΔE_{S-T}). Organic, non-metal containing, donor-acceptor luminescent materials may be able to achieve this. The emission in these materials is often characterized as a donor-acceptor charge-transfer (CT) type emission. The spatial separation of the HOMO and LUMO in these donor-acceptor type compounds often results in small ΔE_{S-T}. These states may involve CT states. Often, donor-acceptor luminescent materials are constructed by connecting an electron donor moiety such as amino- or carbazole-derivatives and an electron acceptor moiety such as N-containing six-membered aromatic rings.

According to an embodiment, donor-acceptor compounds with unexpected CT emission properties are provided. The donor has at least one electron donating nitrogen. The acceptor moiety is based on electron deficient nitrogen containing high triplet energy heteropolyaromatic system.

Donor-acceptor compounds with CT emissions may be useful in high efficiency delayed fluorescence OLED (Appl. Phys. Lett. 2012, 98, 083302; Nature Photonics, 2012, 6, 253; Nature 2012, 492, 234; Chem. Commun. 2012, 48, 11392; Angew. Chem. Int. Ed. 2012, 51, 11311; J. Am. Chem. Soc., 2012, 134, 14706; Chem. Commun. 2012, 48, 9580). The electron acceptors used are triazene or cyano groups. While these groups are strongly electron deficient, making the design of strong donor-acceptor strength easy, OLEDs incorporating them may not be very stable because of the lack of electron delocalization in these acceptors. In this disclosure, we use a high triplet energy heteropolyaromatic system, namely, dibenzofuran, dibenzothiophene and dibenzoselenophene with one or multiple nitrogens in the ring to render a an electron acceptor with high triplet energy. High triplet energy is important in order to obtain blue emission.

According to a preferred embodiment, a donor-acceptor compounds having nitrogen containing dibenzofuran, dibenzothiophene and dibenzoselenophene as an electron acceptor that are unexpectedly suited as delayed fluorescence emitters are disclosed. Such a compound has the structure according to the formula

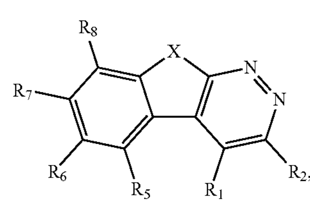
Formula 1



wherein each of Y^1 to Y^8 is C—R or N; at least two of Y^1 to Y^8 are N; at least one of Y^1 to Y^8 is C—R; each R is independently selected from the group consisting of hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrile, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof; wherein at least one of the R is selected from the group of substitutents consisting of D1 through D140; and wherein S_1 to S_7 represent mono, di, tri, tetra or penta substitutions with hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl carboxylic acids, ester, nitrile, isonitrile, sulfanyl, sulfonyl, phosphino, and combinations thereof.

In some embodiments, the donor-acceptor compound is selected from the group consisting of

Formula 2



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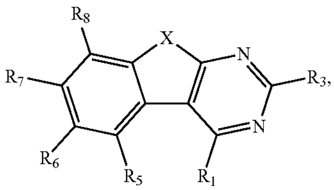

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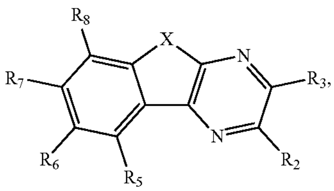

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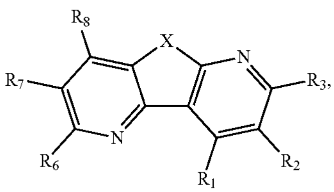

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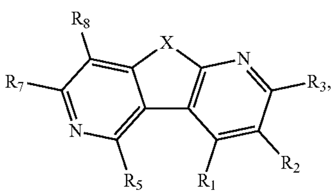

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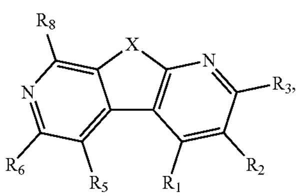

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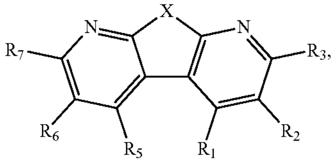

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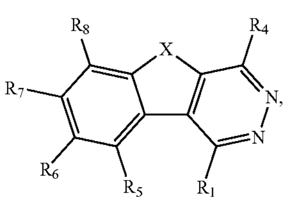

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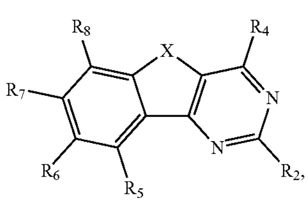

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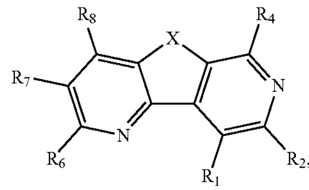

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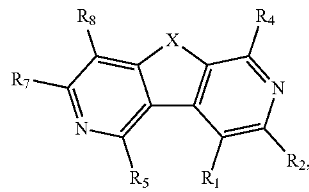

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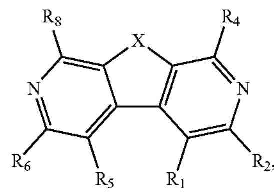

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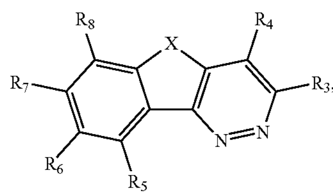

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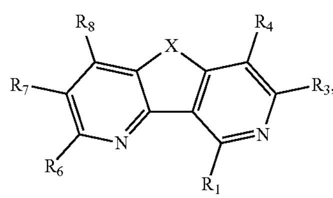

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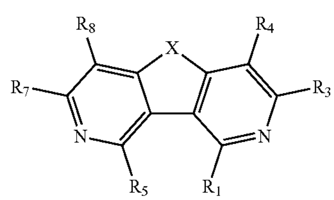
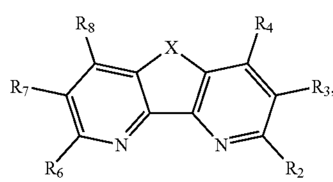


and

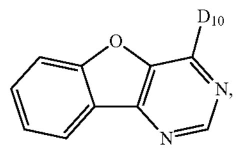
Formula 17



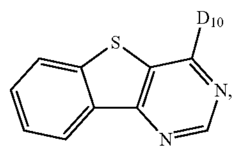
wherein at least one of R_1-R_8 is selected from the group consisting of D1 to D140.

In some more specific embodiments, the compound is selected from the group consisting of:

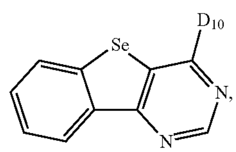
Compound O-10-10



Compound S-10-10



Compound Se-10-10



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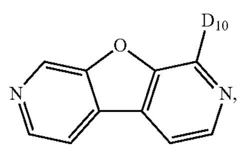

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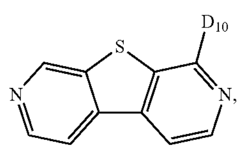

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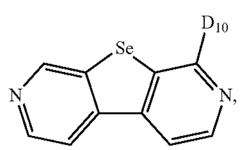

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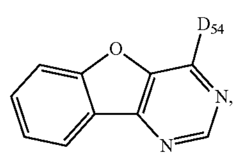

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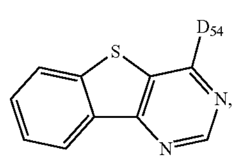

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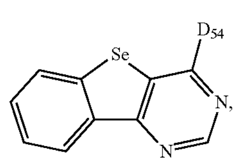

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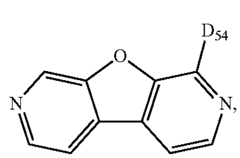

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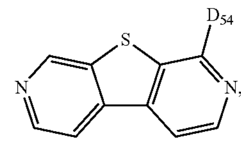
Compound S-13-54



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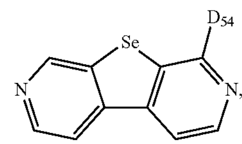

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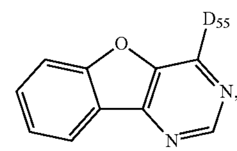

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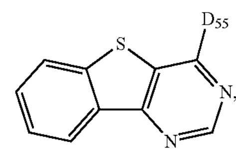

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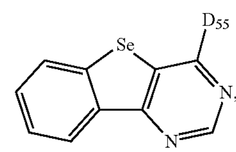
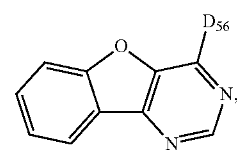
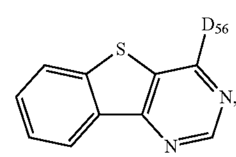


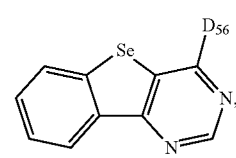
Compound O-10-56



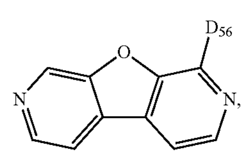
Compound S-10-56



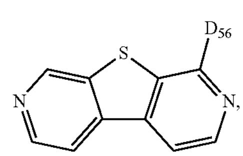
Compound Se-10-56



Compound O-13-56



Compound S-13-56



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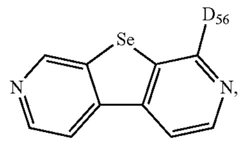
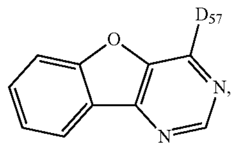
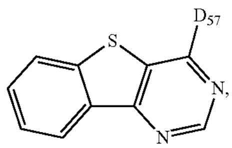
Compound Se-13-56



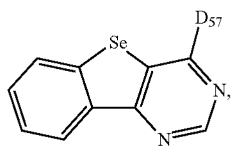
Compound O-10-57



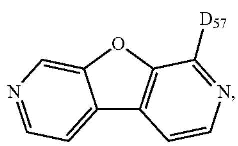
Compound S-10-57



Compound Se-10-57



Compound O-13-57



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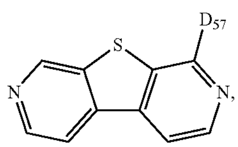
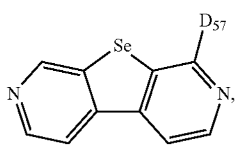
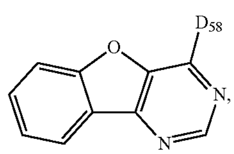


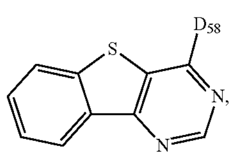
Compound Se-13-57



Compound O-10-58



Compound S-10-58



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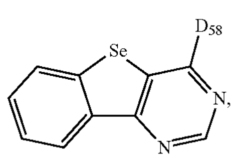

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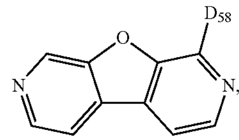
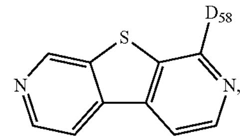
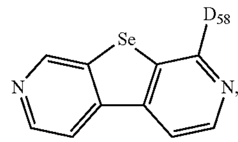
Compound O-13-58



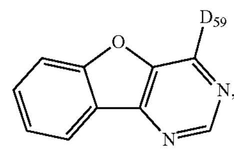
Compound S-13-58



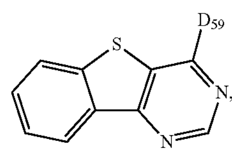
Compound Se-13-58



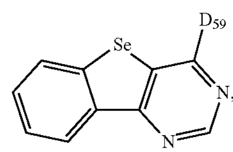
Compound O-10-59



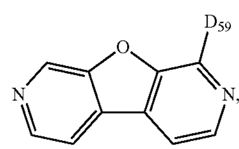
Compound S-10-59



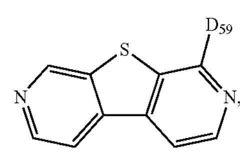
Compound Se-10-59



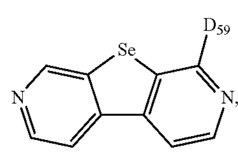
Compound O-13-59



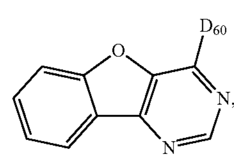
Compound S-13-59



Compound Se-13-59



Compound O-10-60



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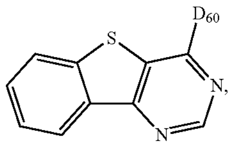
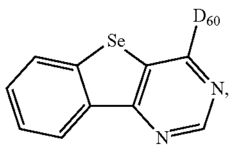
Compound S-10-60



Compound Se-10-60



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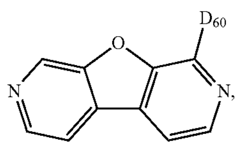
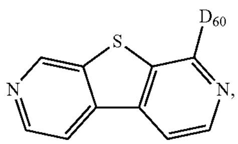
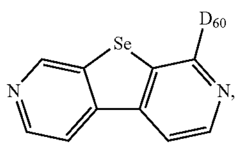


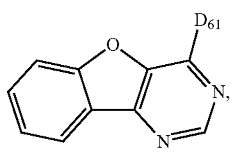
Compound S-13-60



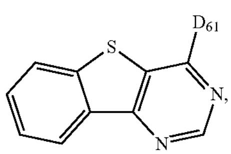
Compound Se-13-60



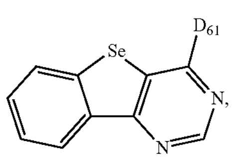
Compound O-10-61



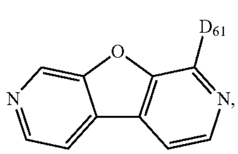
Compound S-10-61



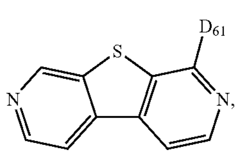
Compound Se-10-61



Compound O-13-61



Compound S-13-61



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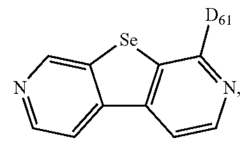
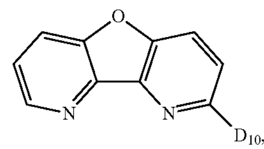
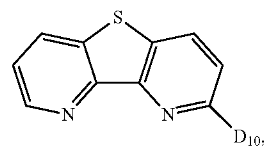
Compound Se-13-61



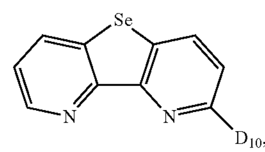
Compound O-17-10



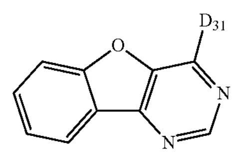
Compound S-17-10



Compound Se-17-10

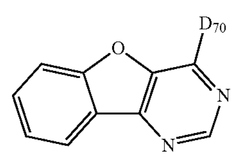


Compound O-10-31



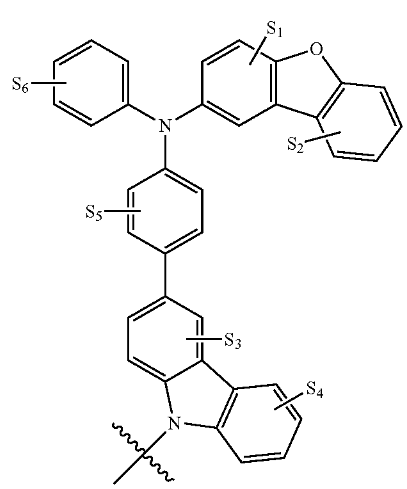
and

Compound O-10-70



wherein D10, D31, D54, D55, D56, D57, D58, D59, D60, D70 and D61 are

D10



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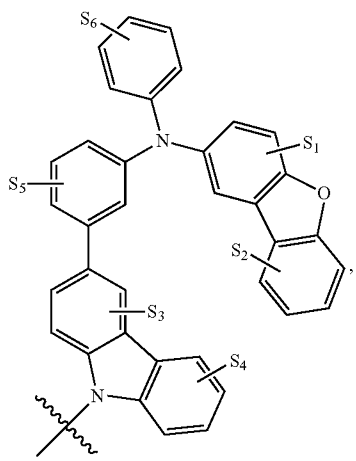
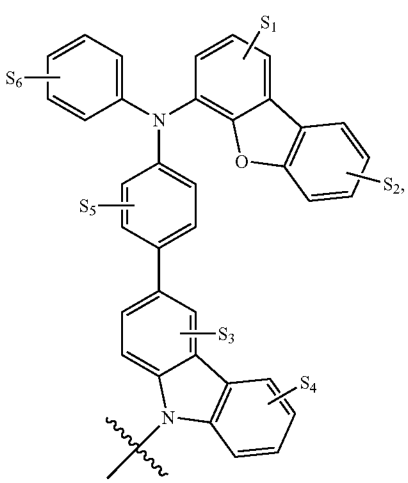
D31



D54



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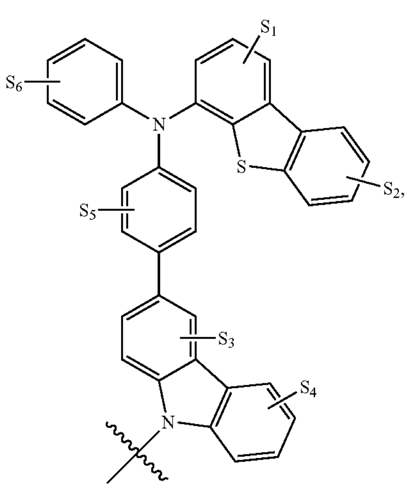

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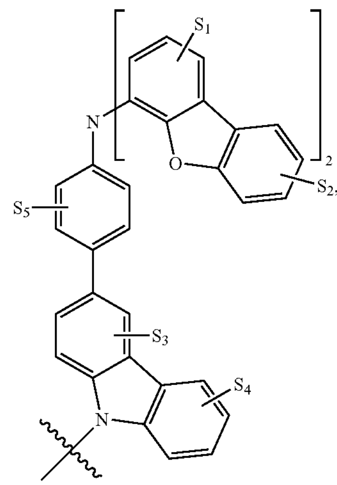
D56



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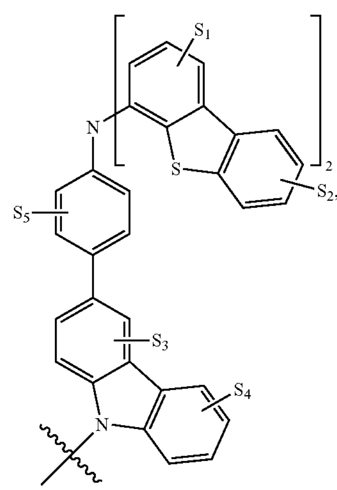

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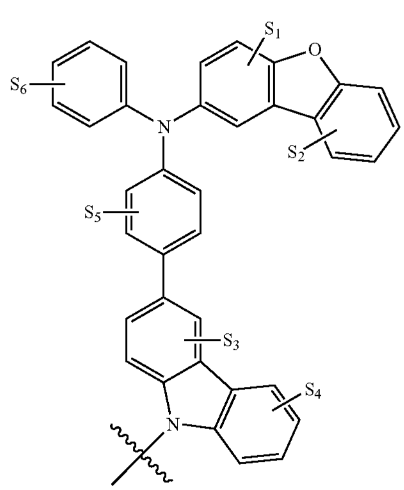

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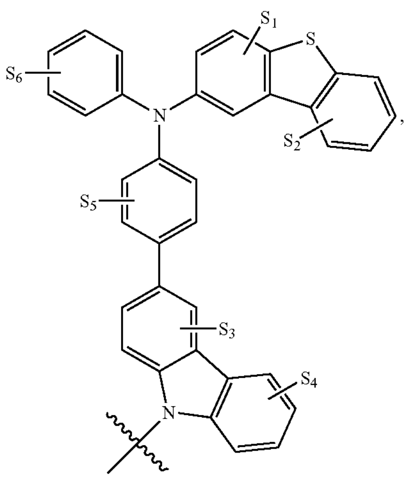
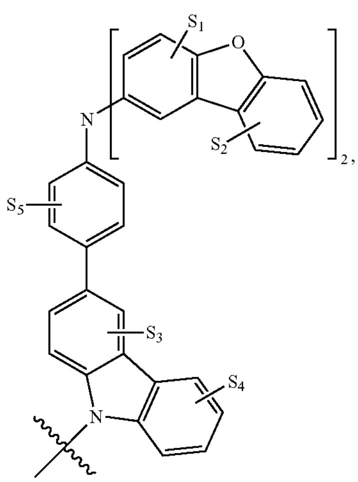
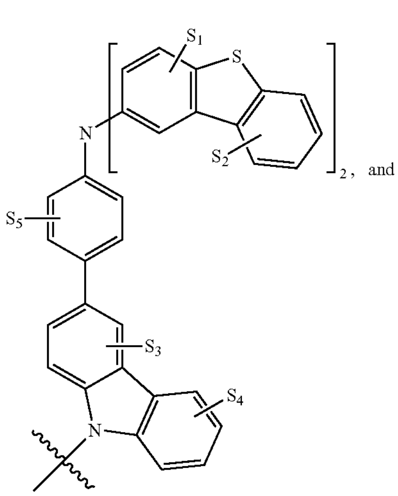
D59



D60



D61



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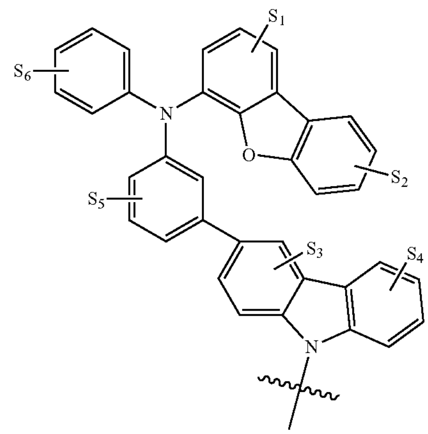
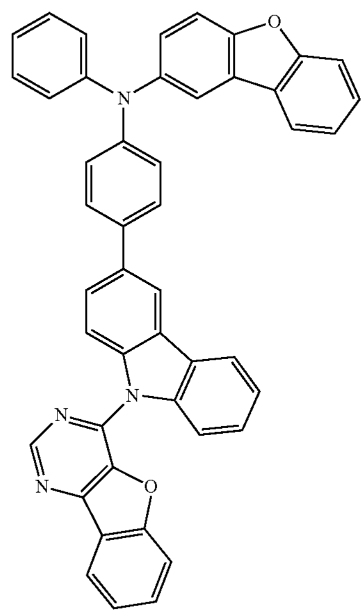
D70



wherein S_1 to S_6 represent mono, di, tri, tetra or penta substitutions with hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrile, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof.

In some embodiments of the donor-acceptor compound, S_1 to S_6 are H. The resulting compounds are denoted as Compound No.-H. For example, Compound O-10-10-H is

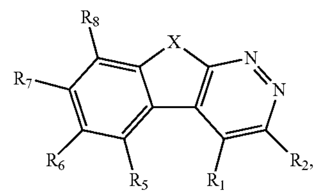
Compound O-10-10-H



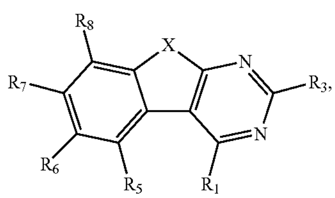
According to another aspect of the present disclosure, a first device that includes a first organic light emitting device is provided. The organic light emitting device comprises an anode, a cathode, and an organic emissive layer disposed between the anode and the cathode. The organic emissive layer comprises a first emitting compound having the structure according to Formula 1, wherein each of Y^1 to Y^8 is C—R or N; at least one of Y^1 to Y^8 is N; at least one of Y^1 to Y^8 is C—R; each R is independently selected from the group consisting of hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrile, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof; and wherein at least one of the R comprises a donor group with at least one electron-donating nitrogen. In another embodiment of the first device, at least two of Y^1 to Y^8 is N.

In some specific embodiments, the first emitting compound is selected from the group consisting of

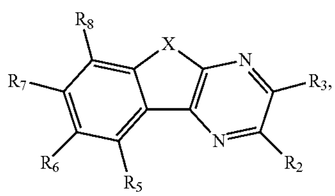
Formula 2



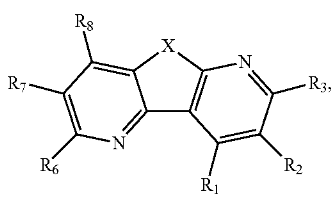
Formula 3



Formula 4



Formula 5



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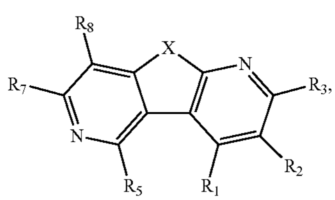
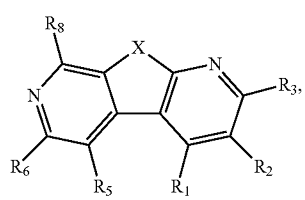
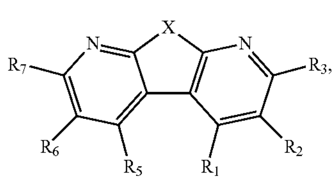


Formula 7



Formula 8



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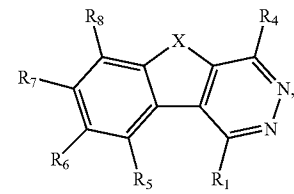
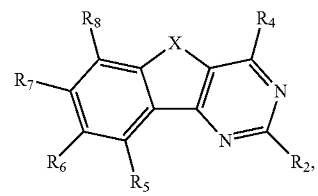
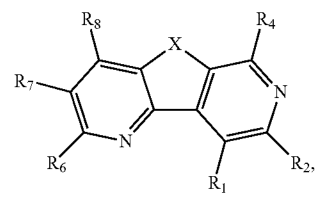
Formula 9



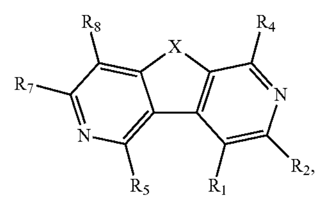
Formula 10



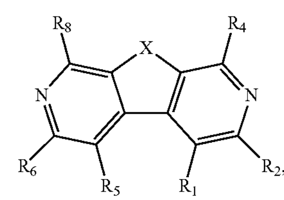
Formula 11



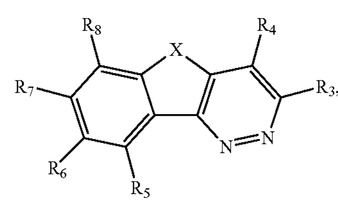
Formula 12



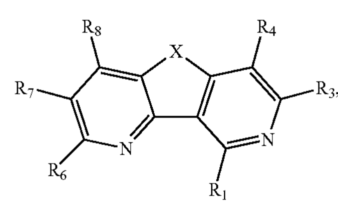
Formula 13



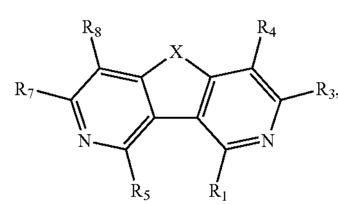
Formula 14



Formula 15



Formula 16



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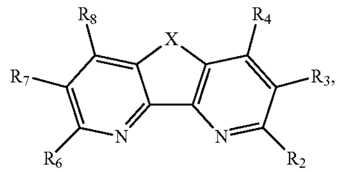
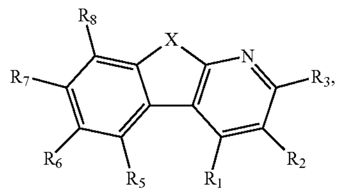
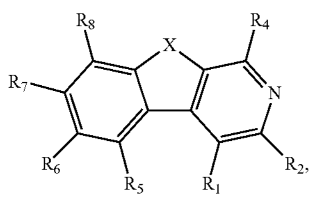


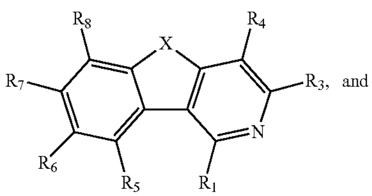
Formula 17



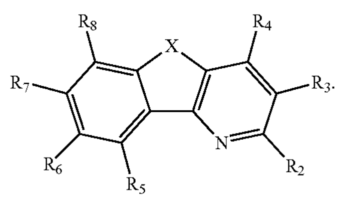
Formula 18



Formula 19



Formula 20



Formula 21

wherein R_1-R_8 is independently hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrile, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof;

at least one of R_1 to R_8 is $(L\text{—})_m\text{—}(\text{Donor})_n$;

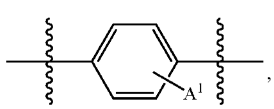
wherein L is a linker,

m is 1 or 0,

n≥1; and

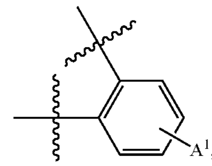
wherein Donor is an electron donating group containing at least one electron-donating nitrogen and Donors can be different when n>1.

The linker L can be one of

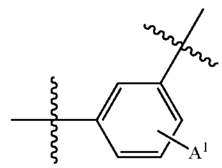


L1

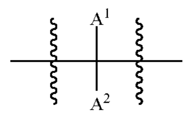
-continued



L2

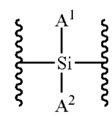


L3



L4

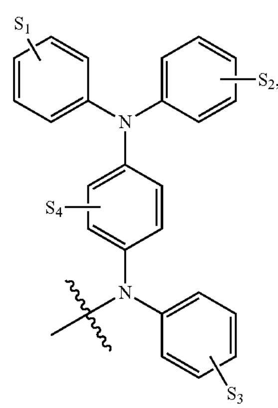
, or



L5

wherein A^1 to A^2 represent mono, di, tri or tetra substitutions with hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrile, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof.

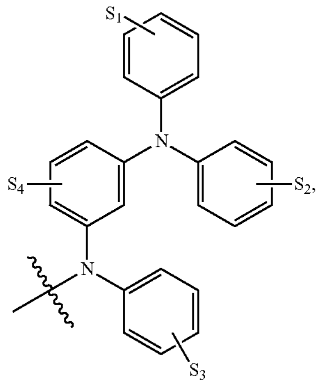
In some embodiments, the Donor is selected from the group consisting of D1 through D144 shown below:



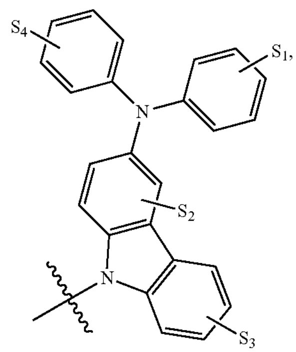
D1

-continued

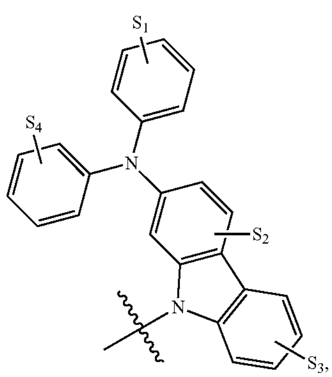
D2



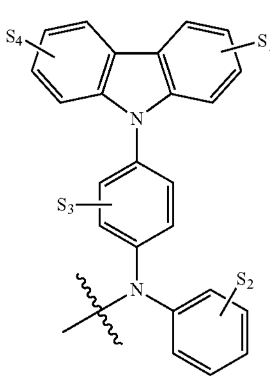
D3



D4



D5



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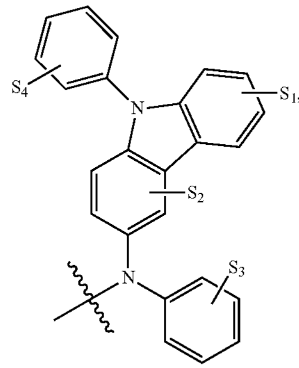
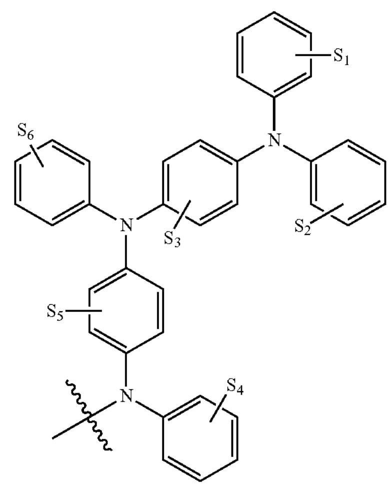
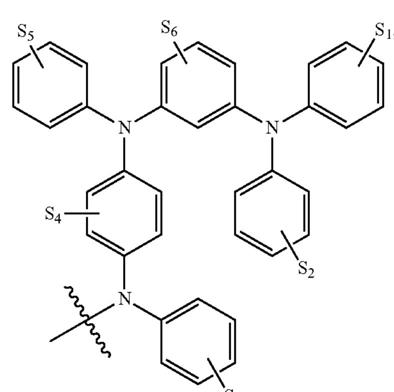
D6



D7



D8



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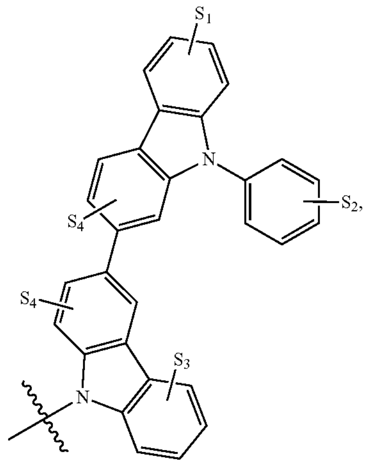
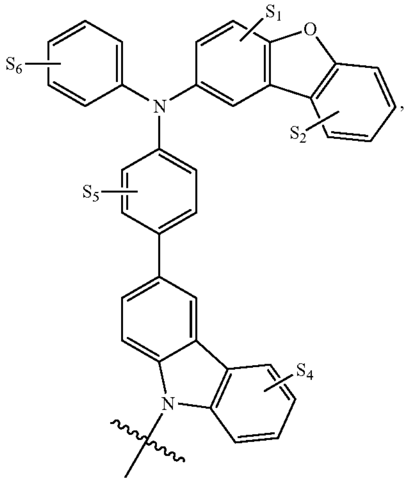
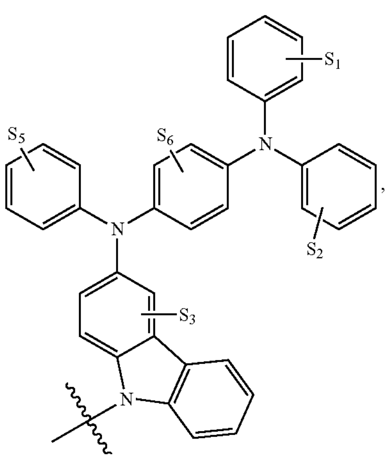
D9



D10



D11



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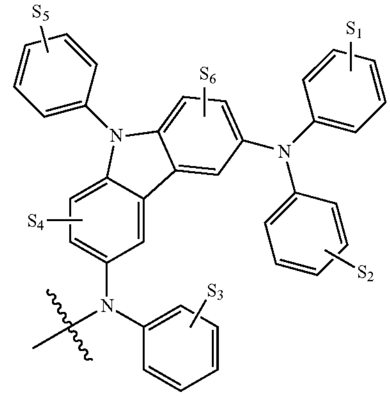
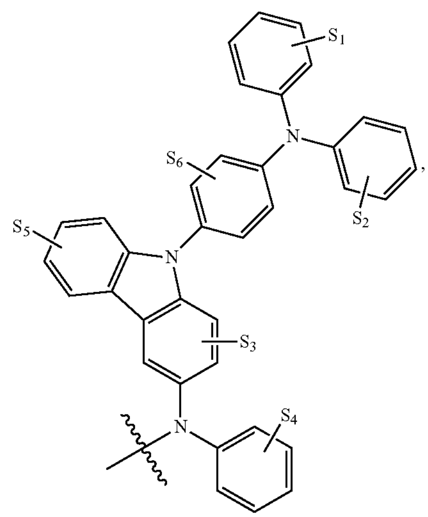
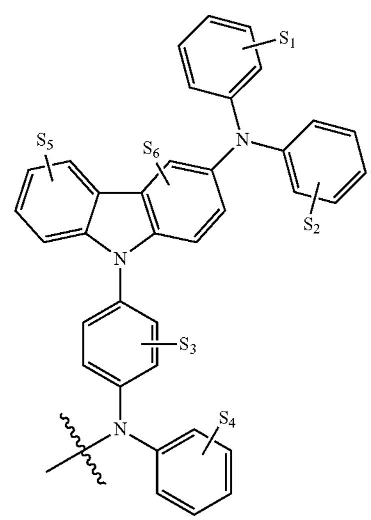
D12



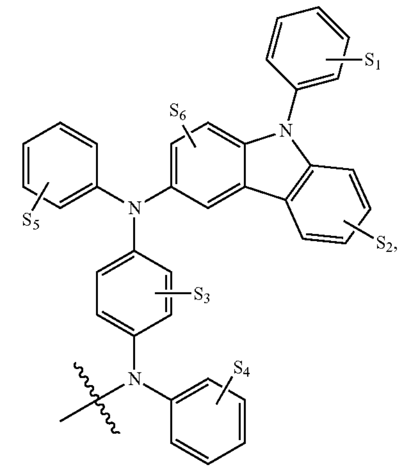
D13



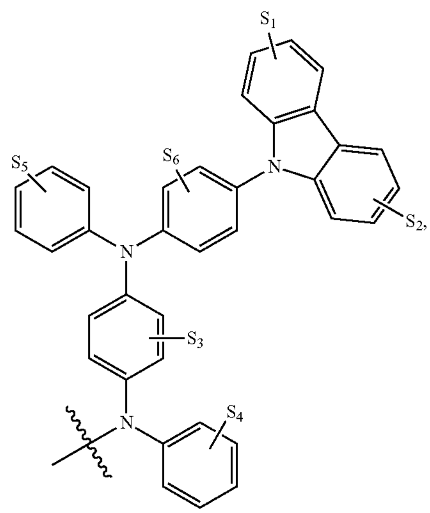
D14



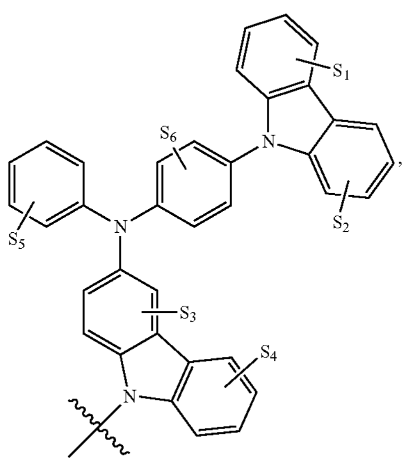
D15



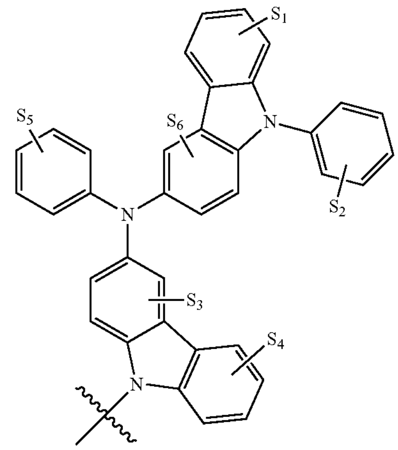
D16



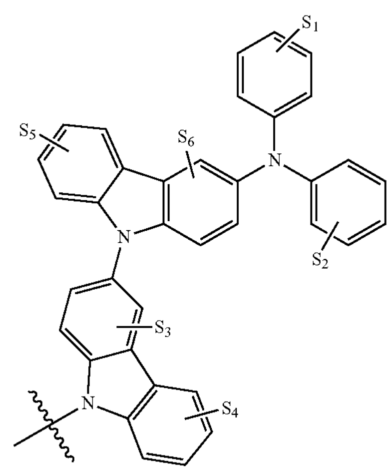
D17



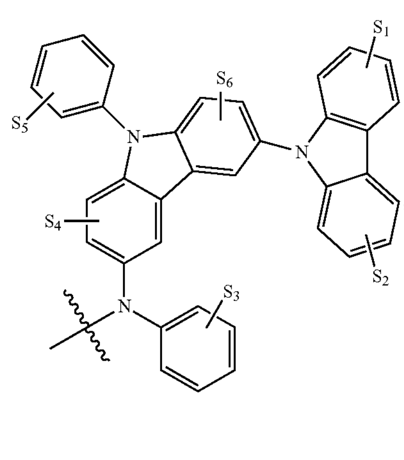
D18



D19



D20



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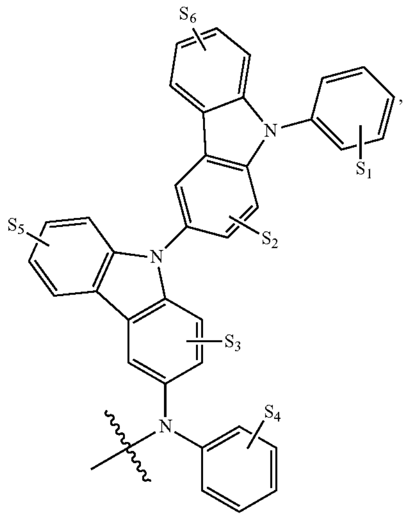
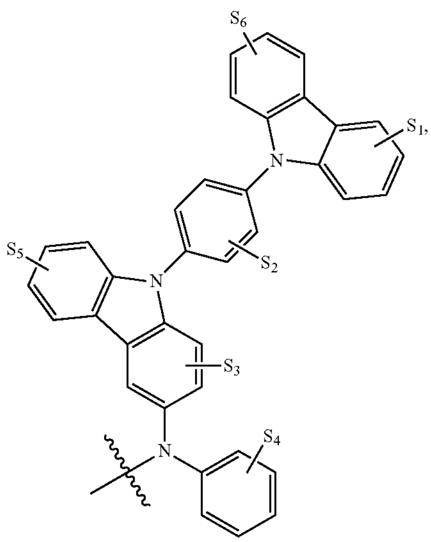
D21



D22



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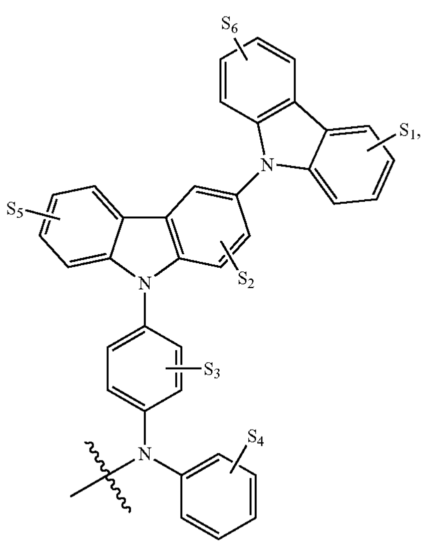

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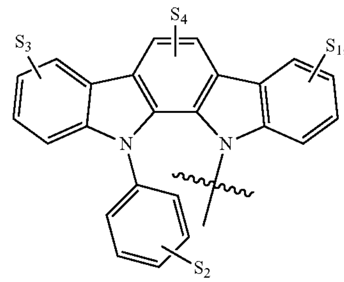
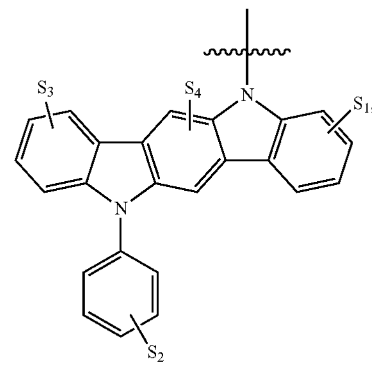
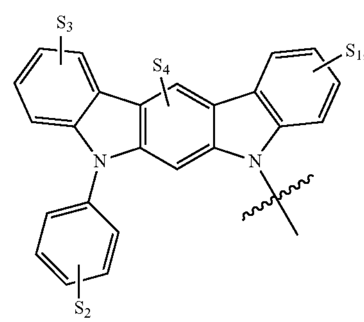
D24



D25



D26



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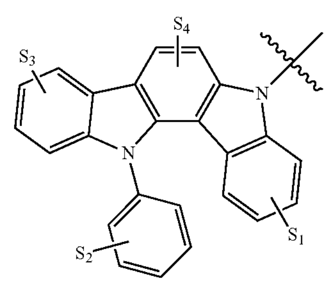

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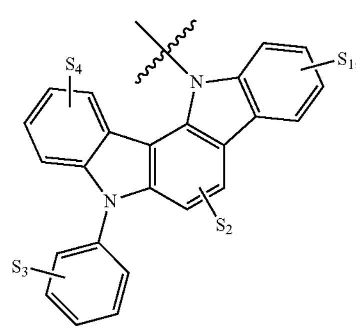

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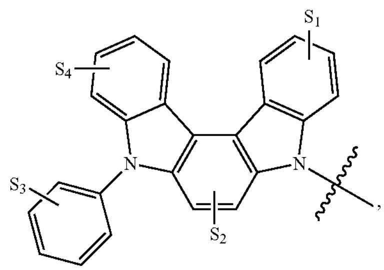

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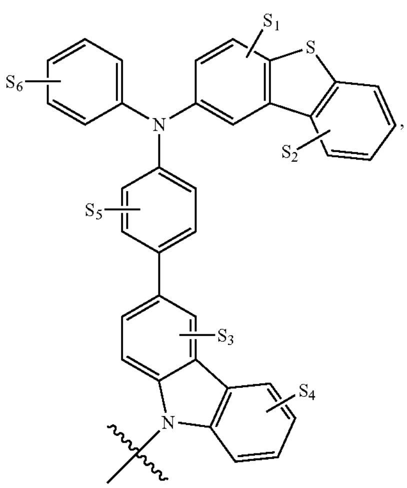

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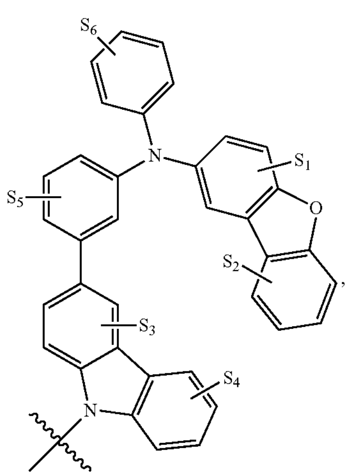

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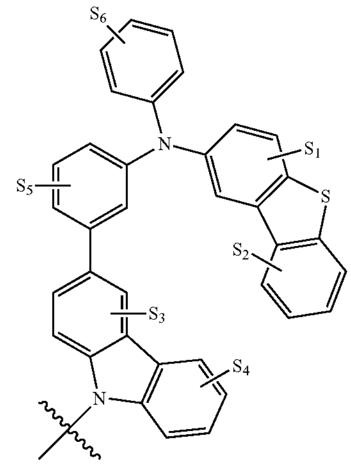

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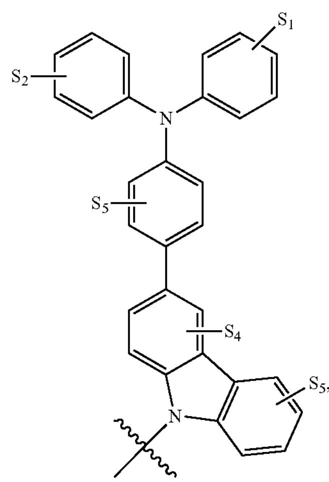

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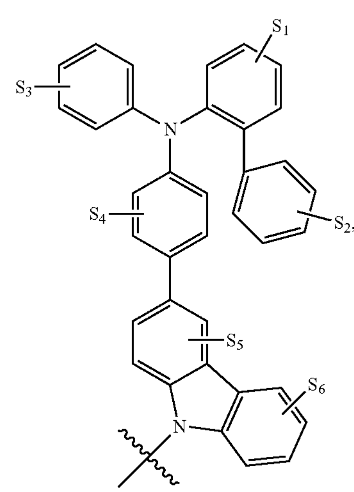

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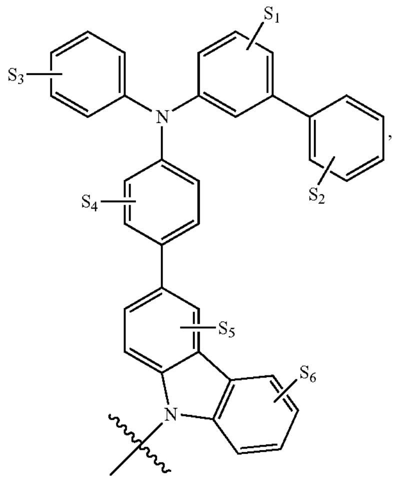
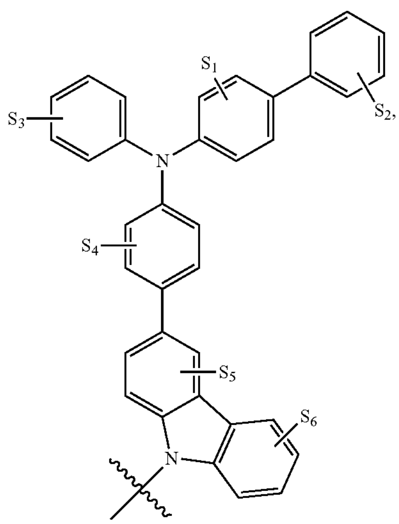
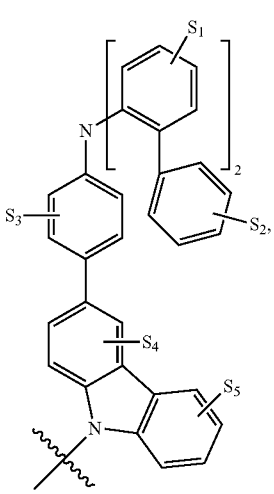
D35



D36



D37



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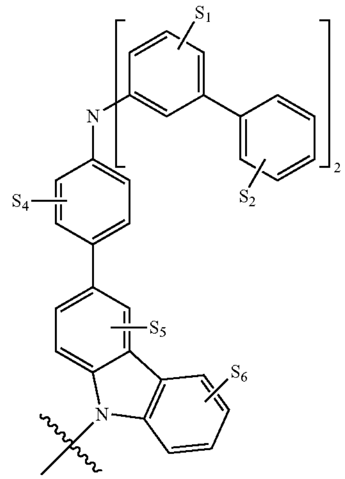
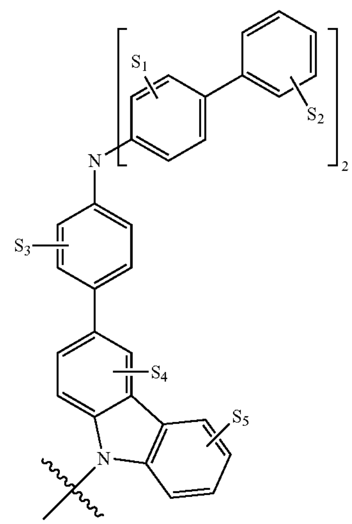
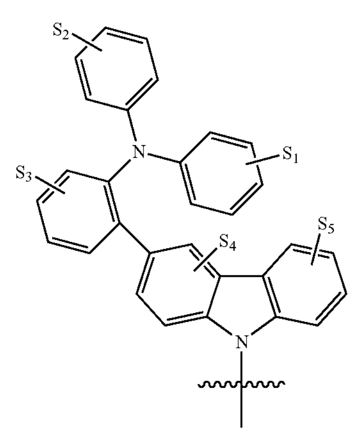
D38



D39



D40



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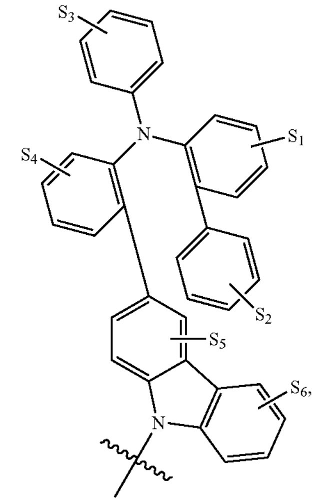
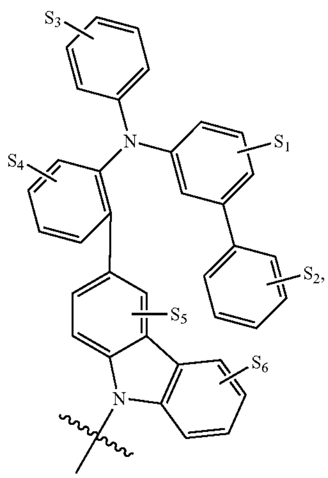
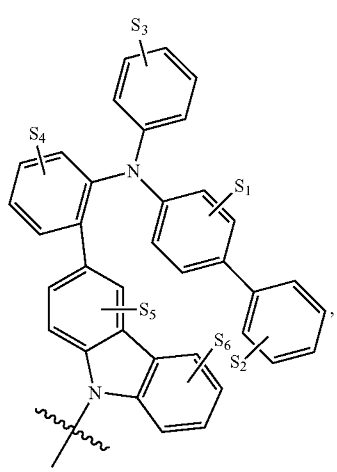
D41



D42



D43



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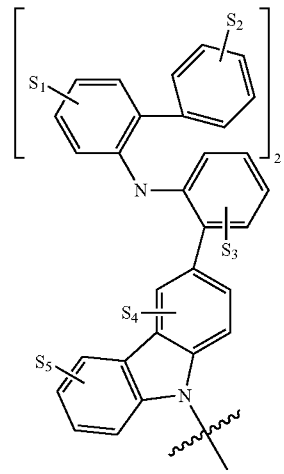
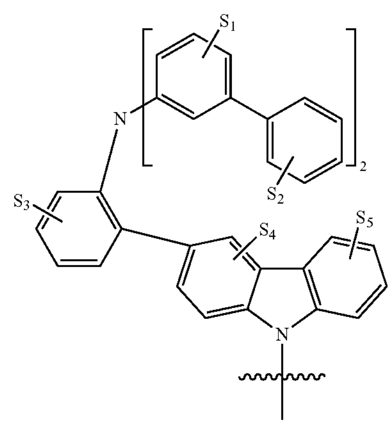
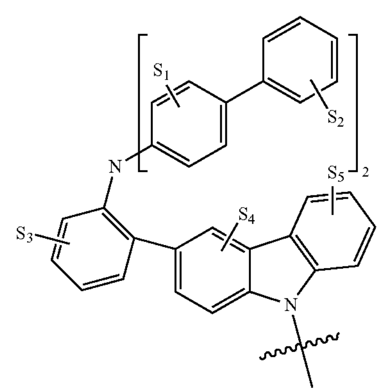
D44



D45



D46



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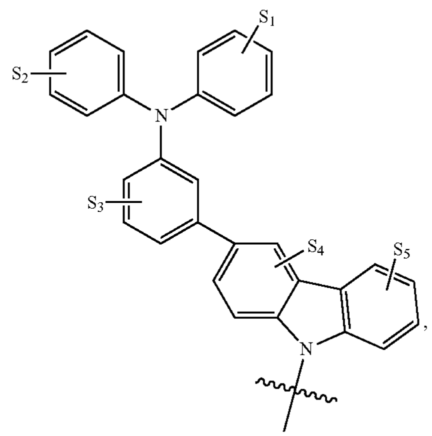
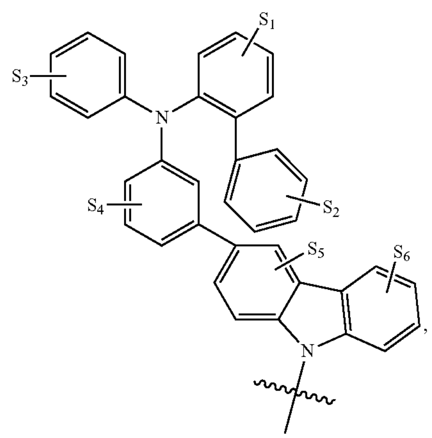
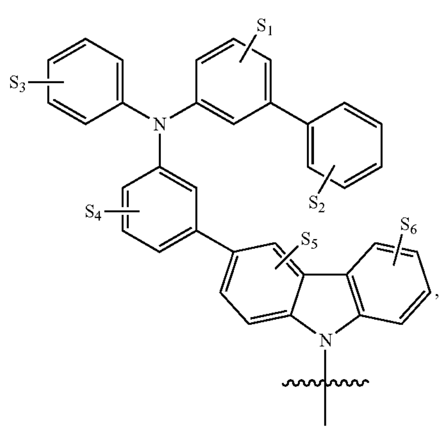
D47



D48



D49



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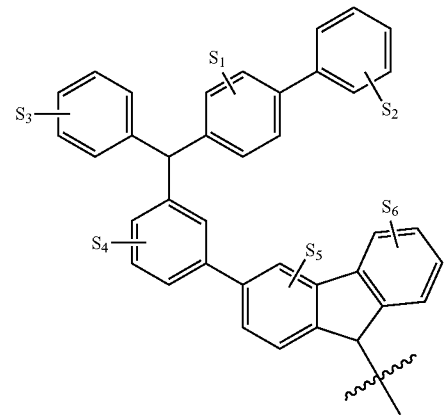
D50



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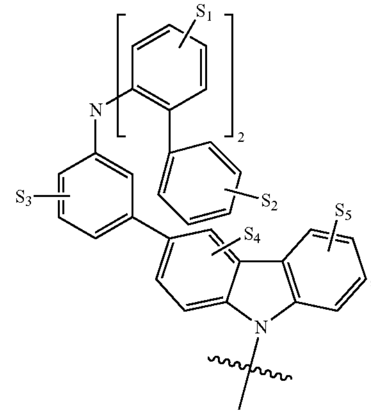
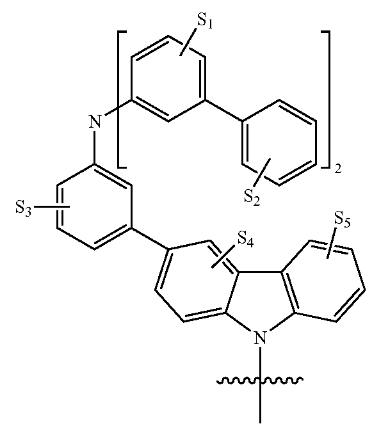


D52



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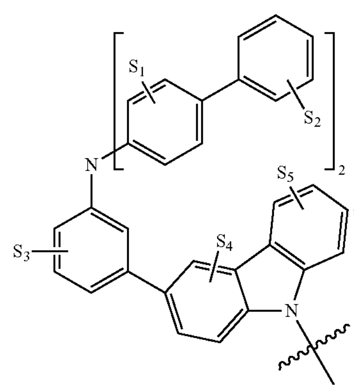
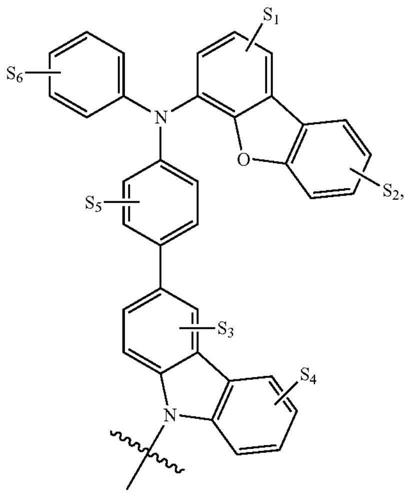
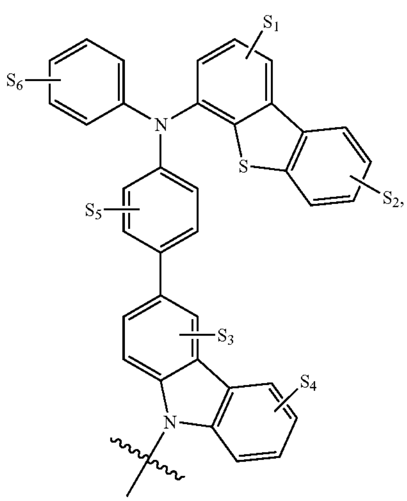


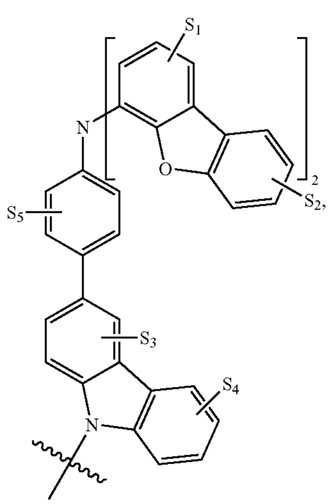
D54



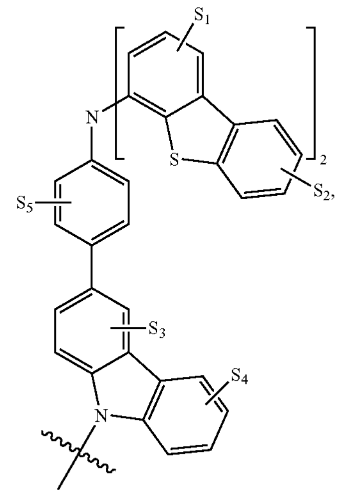
D55



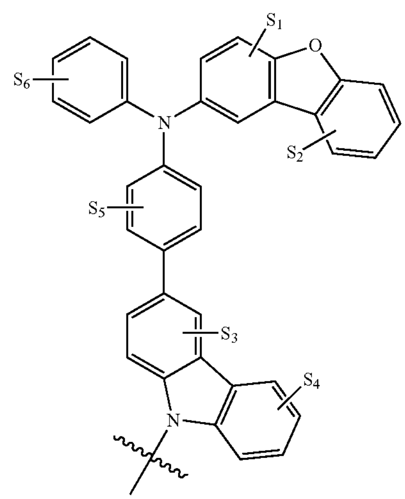
D56



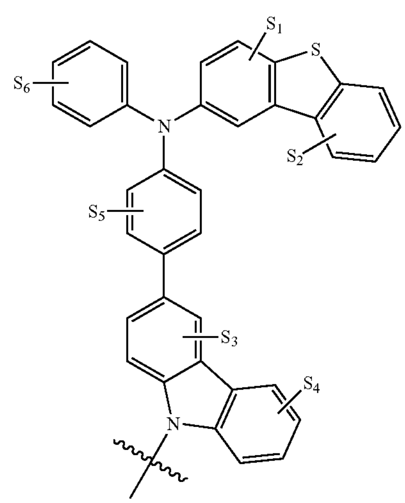
D57



D58



D59



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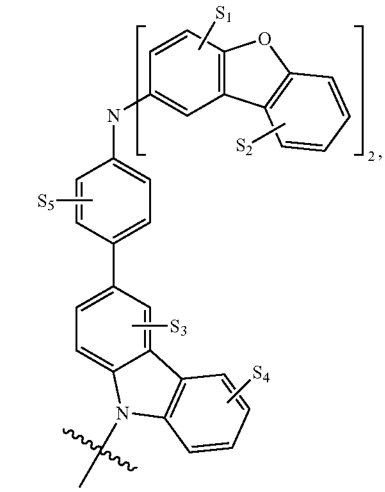
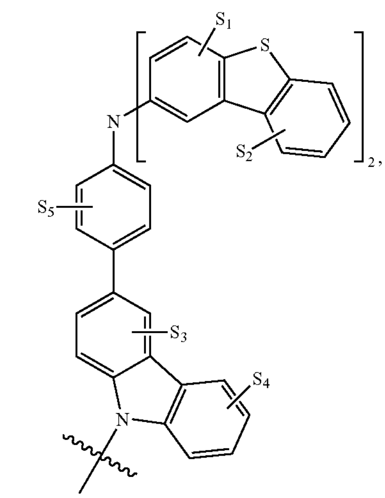
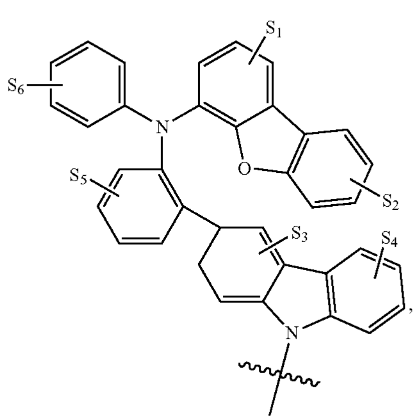
D60



D61



D62



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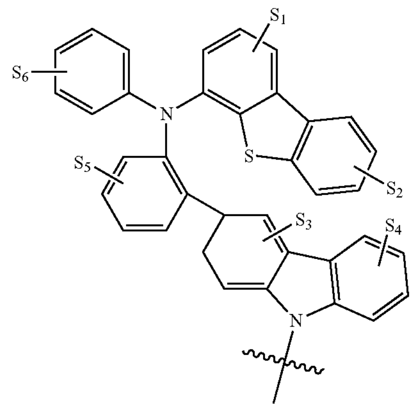
D63



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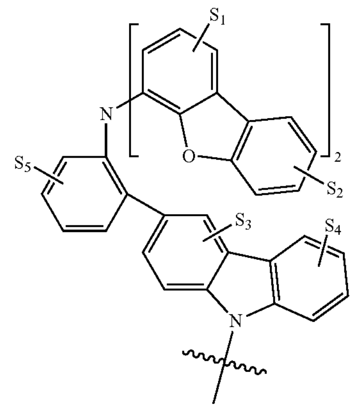

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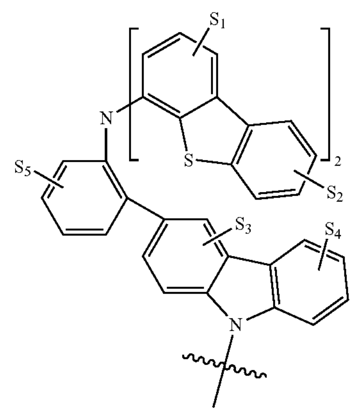

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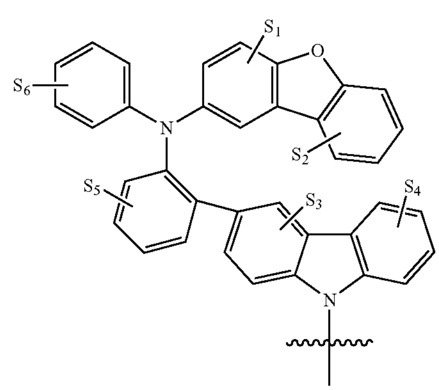

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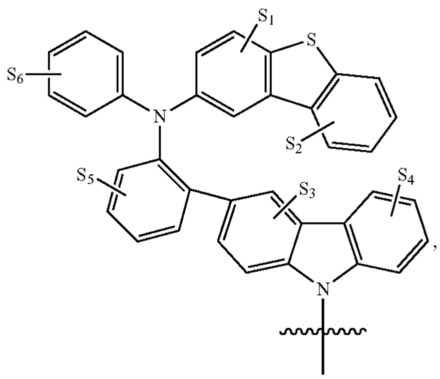

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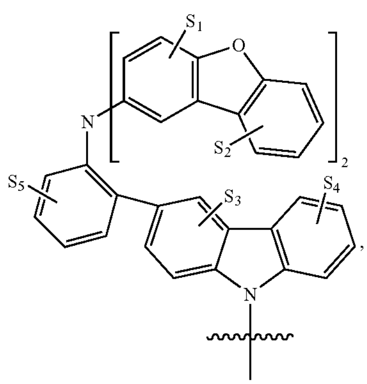

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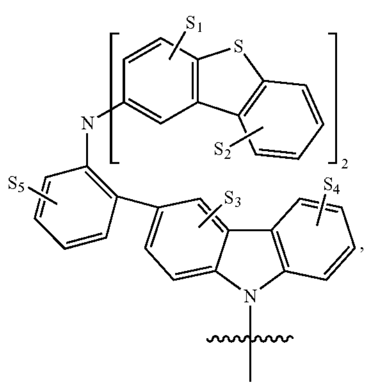

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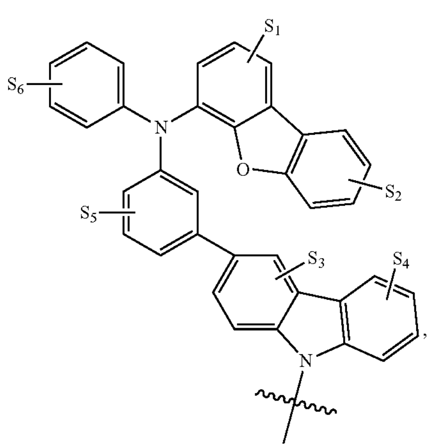

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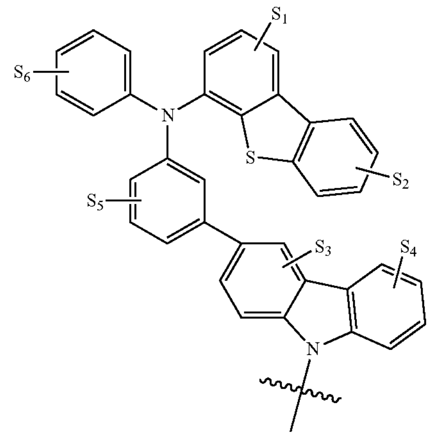

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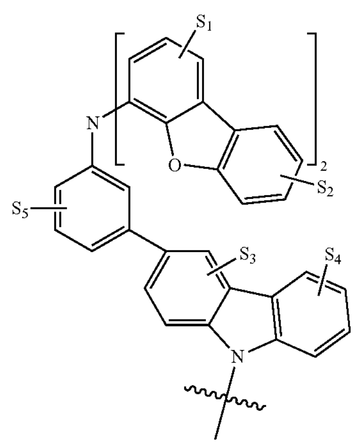

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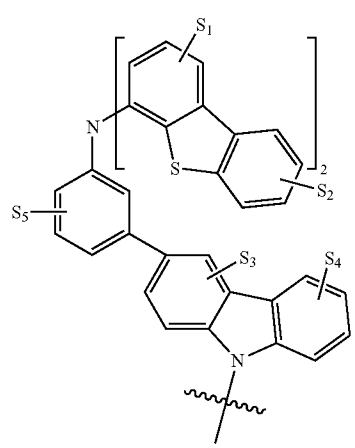

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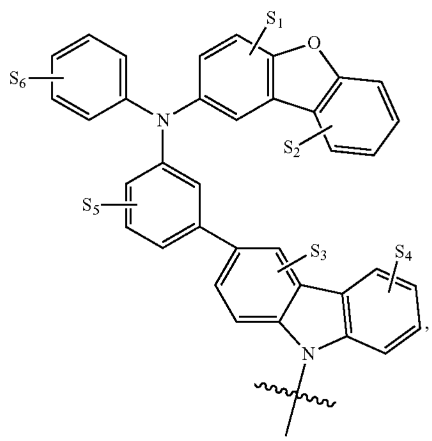

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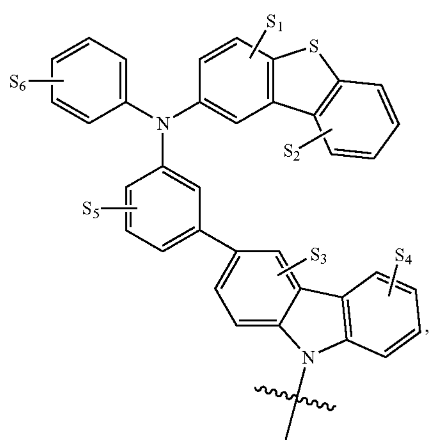

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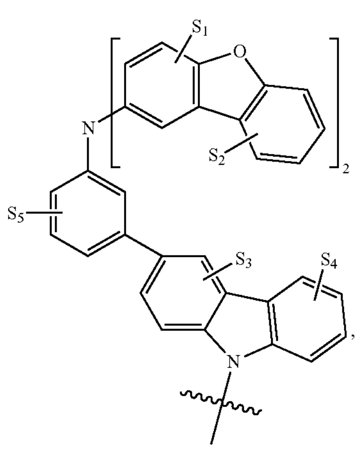

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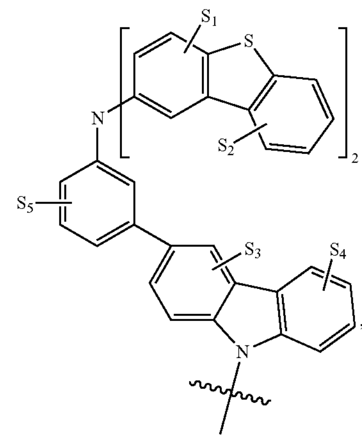

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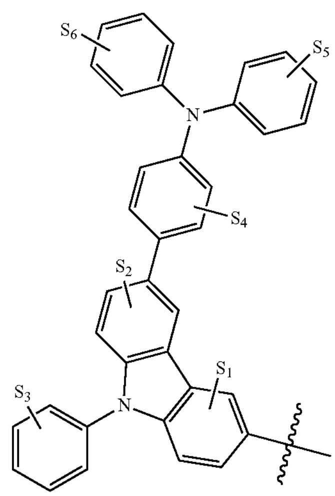

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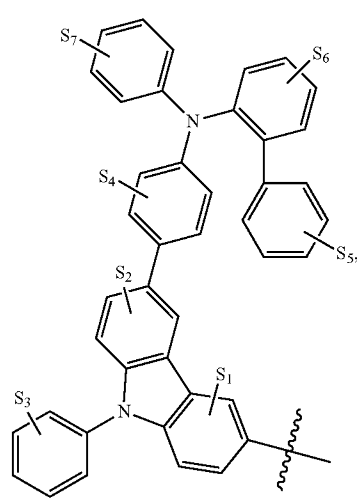

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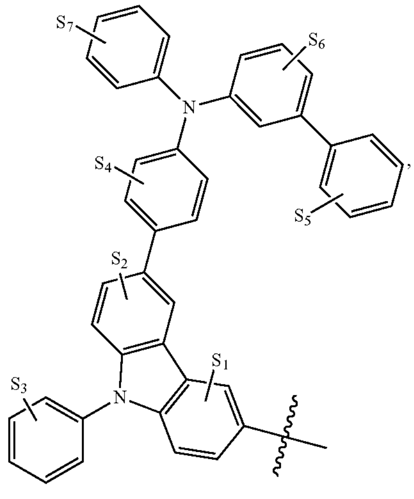

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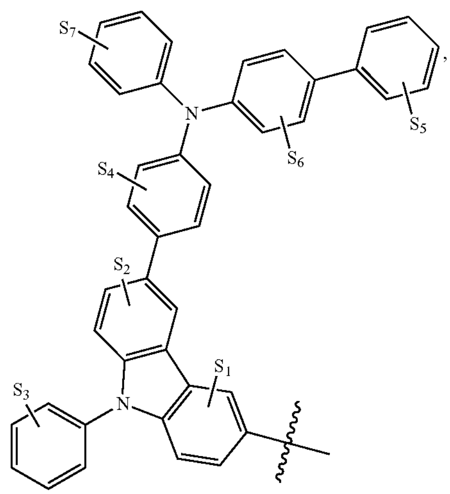

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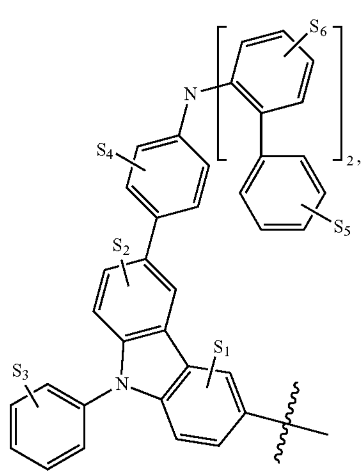

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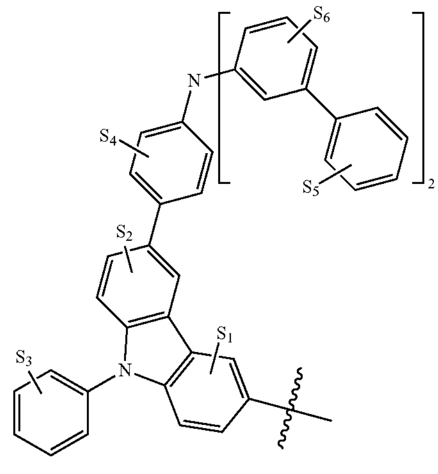

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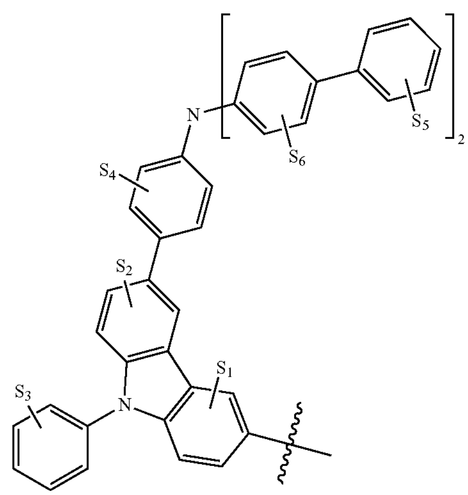

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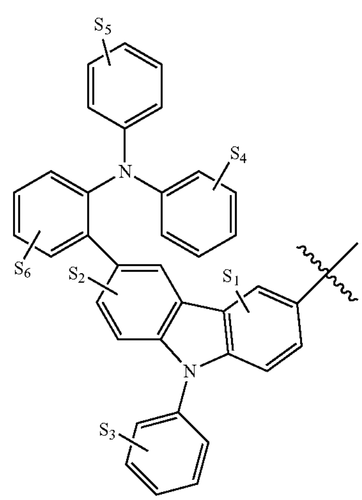

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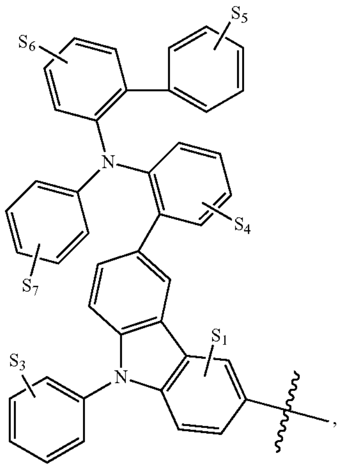

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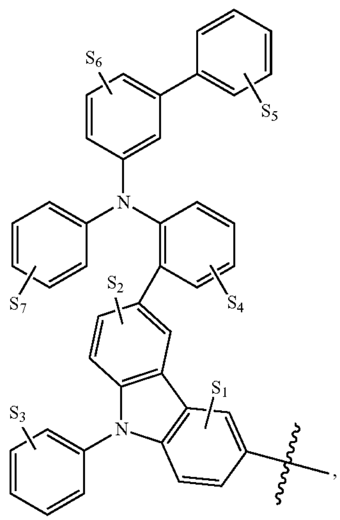

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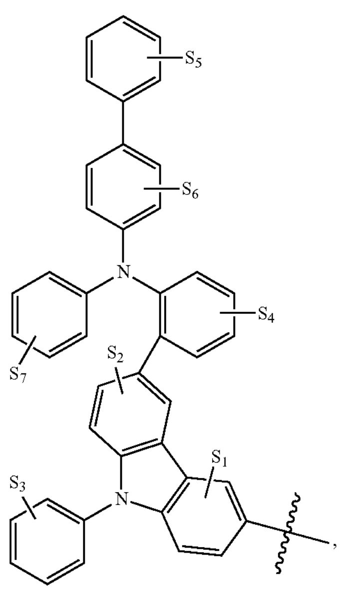

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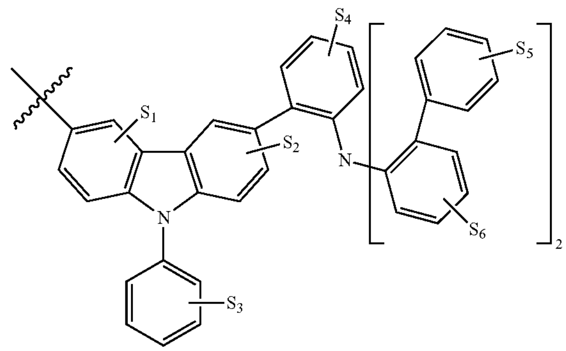

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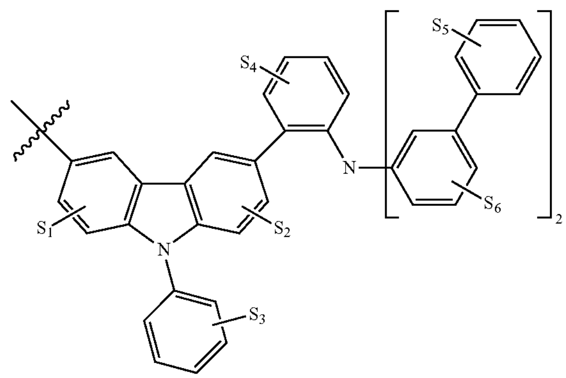

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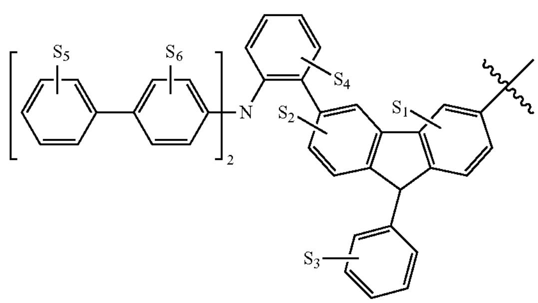

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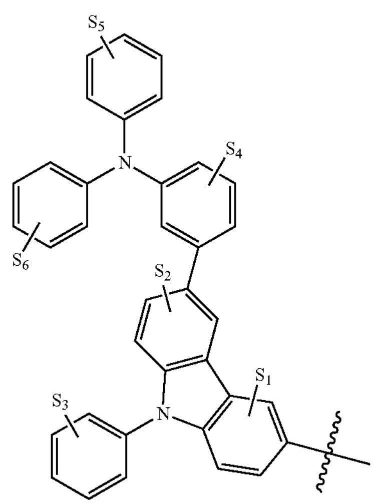

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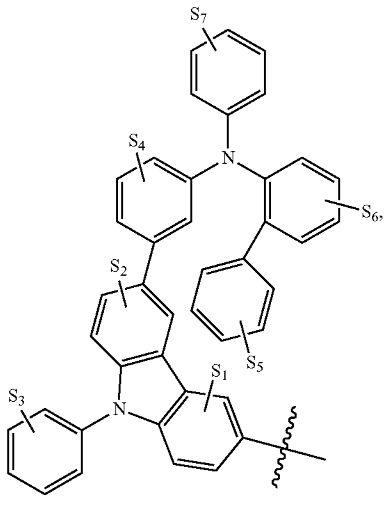

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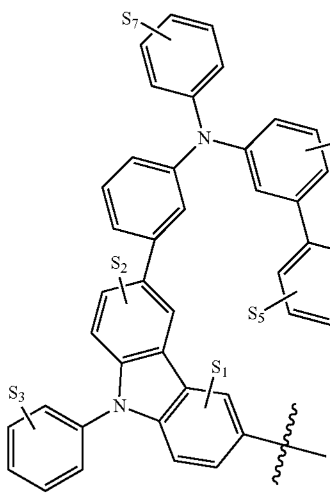

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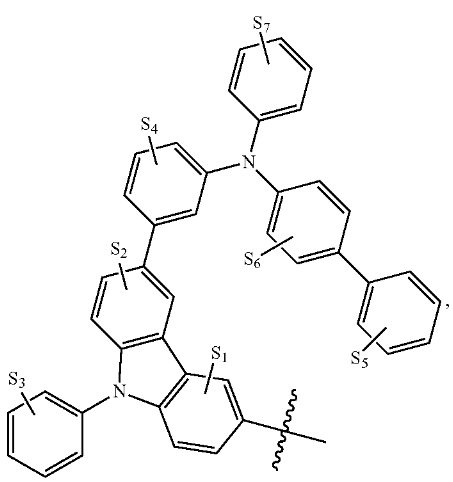

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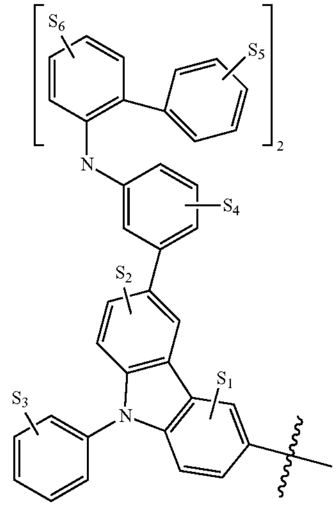

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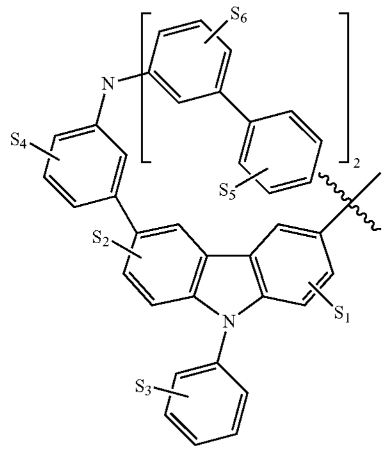

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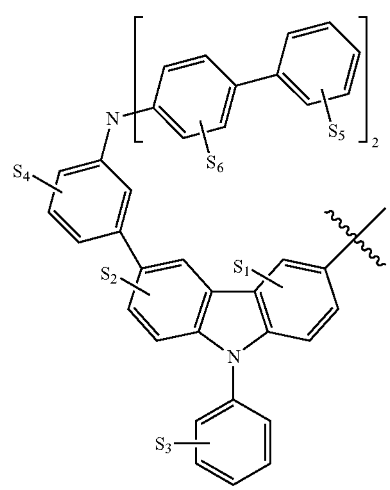

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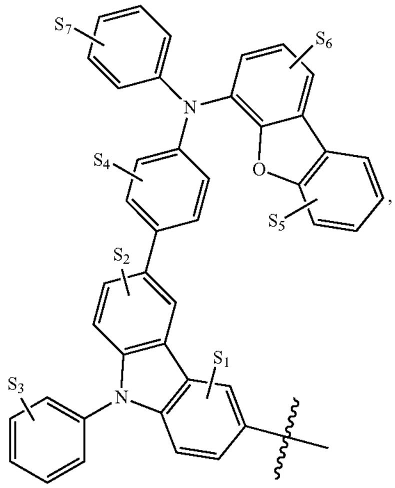

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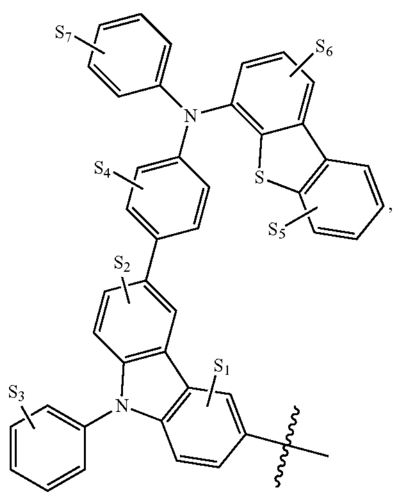

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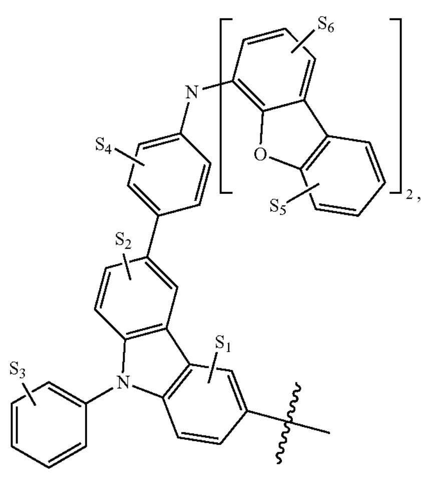

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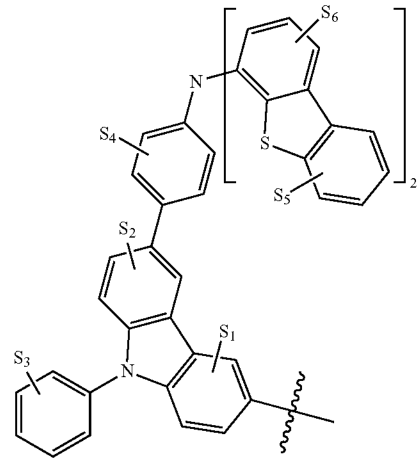

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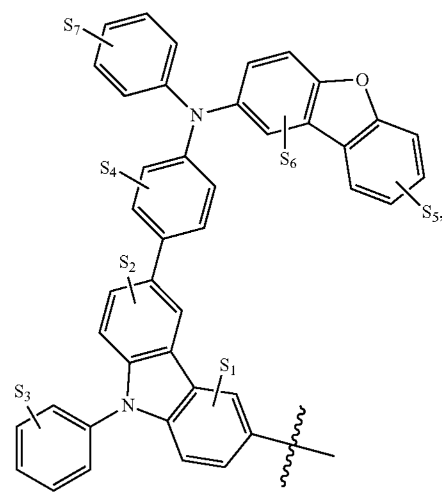

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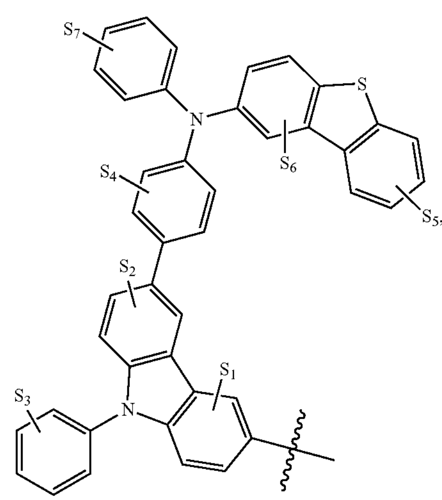

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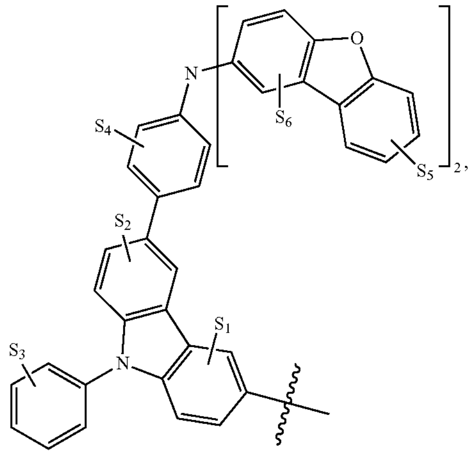

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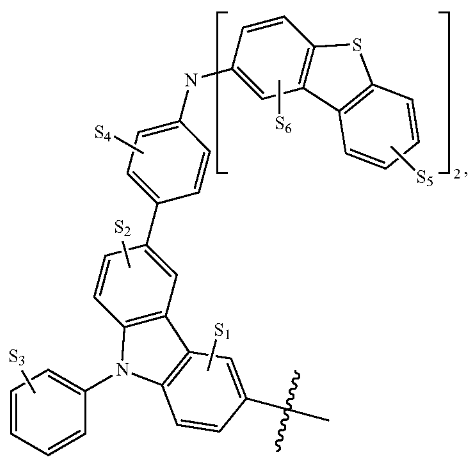

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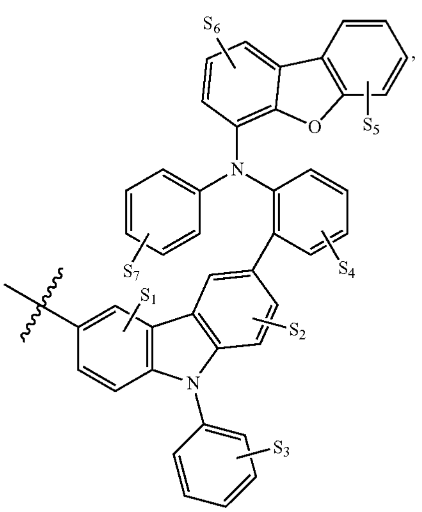

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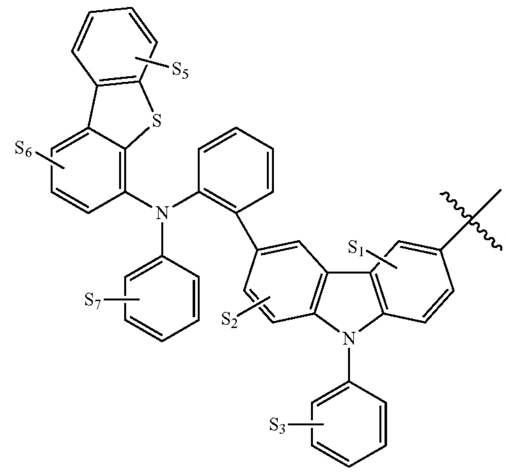

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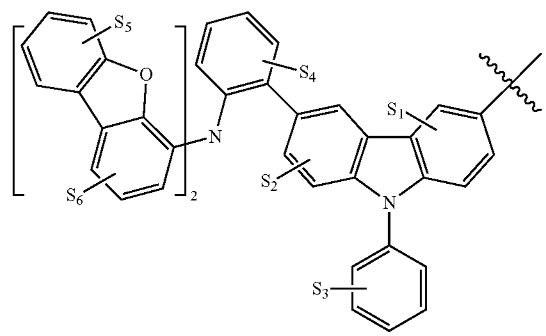

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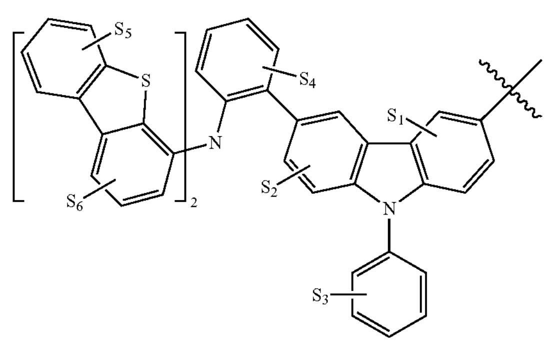

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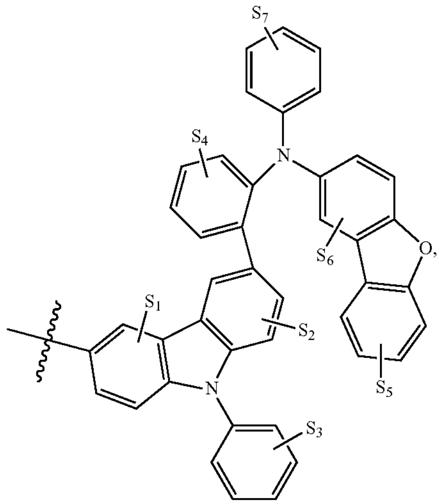

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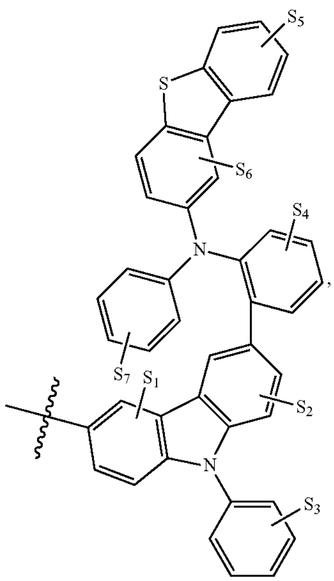

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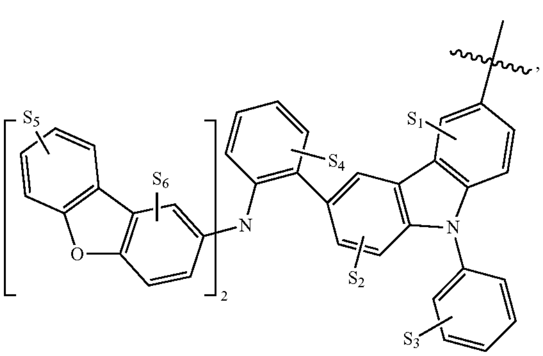

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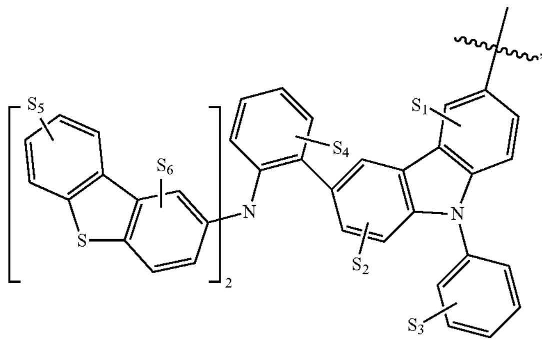

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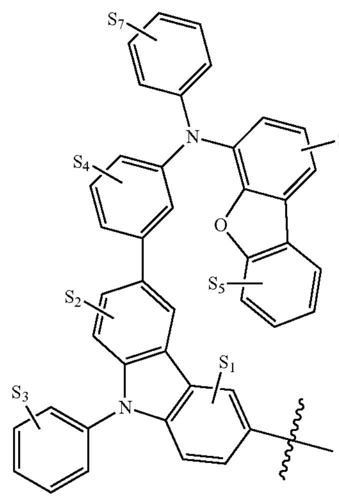

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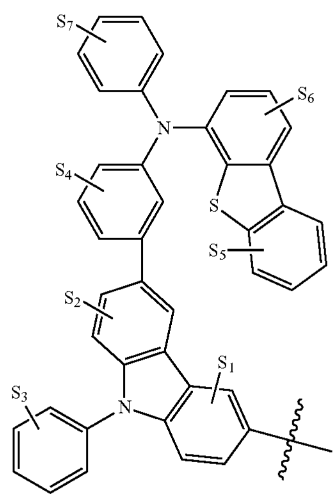

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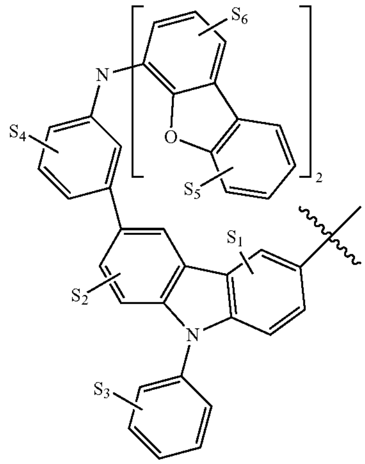

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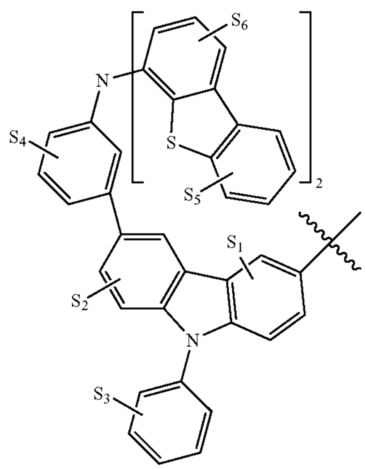

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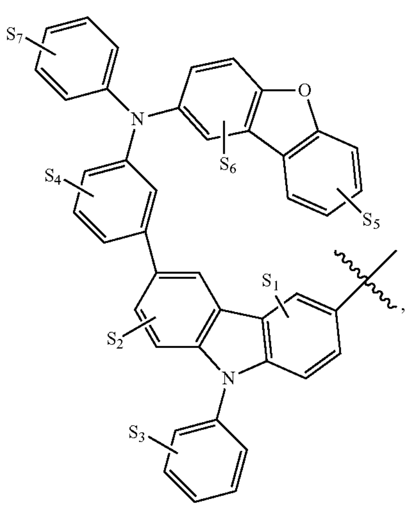

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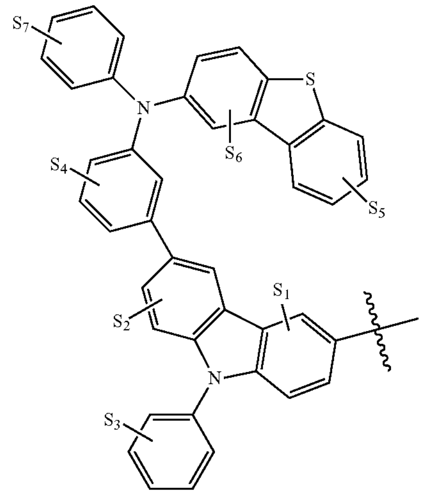

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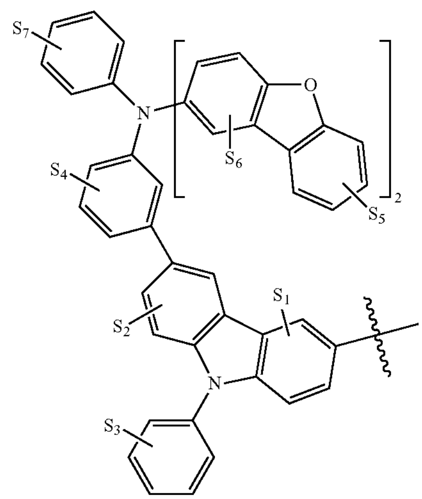

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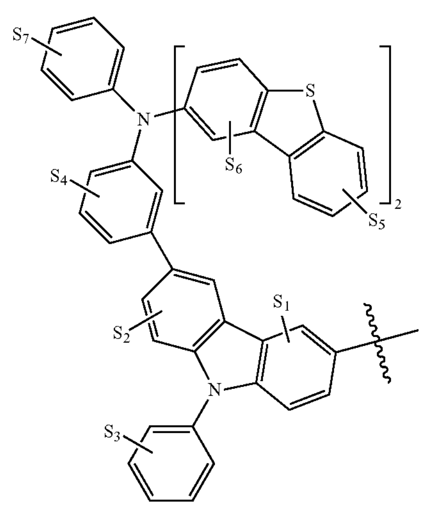

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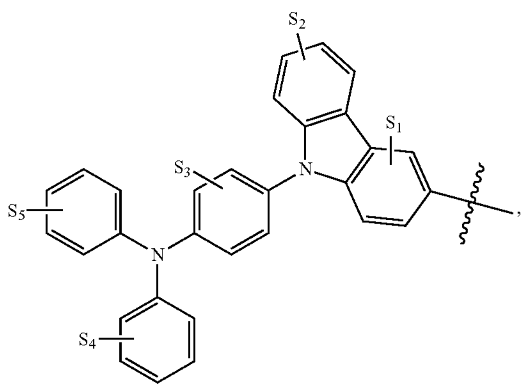

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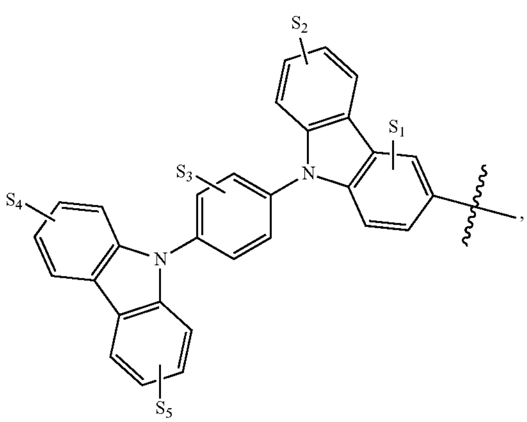

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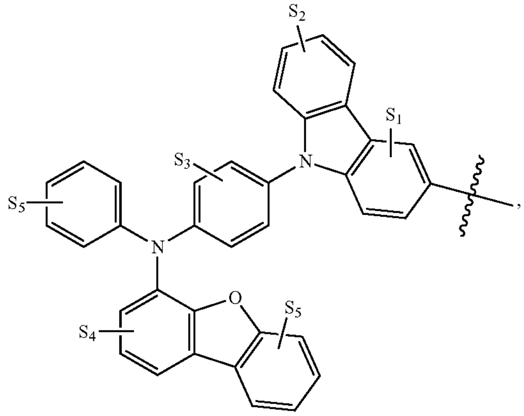

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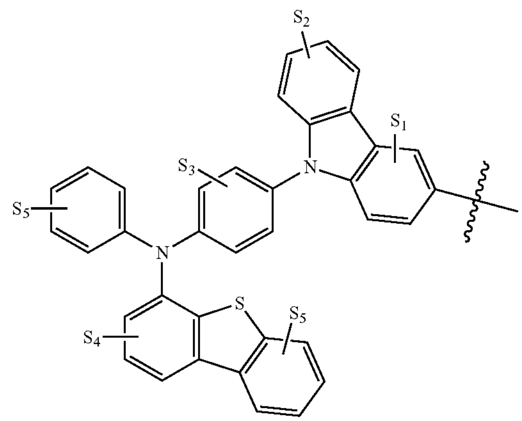

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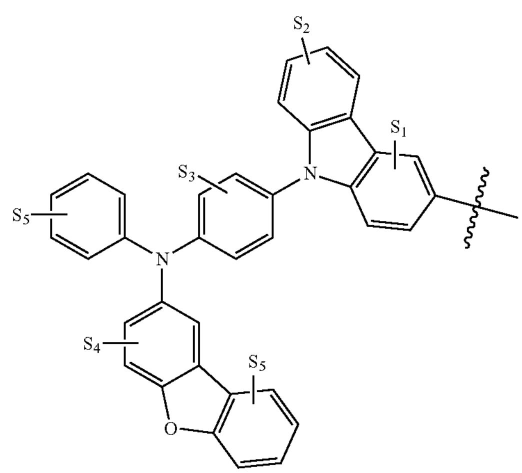

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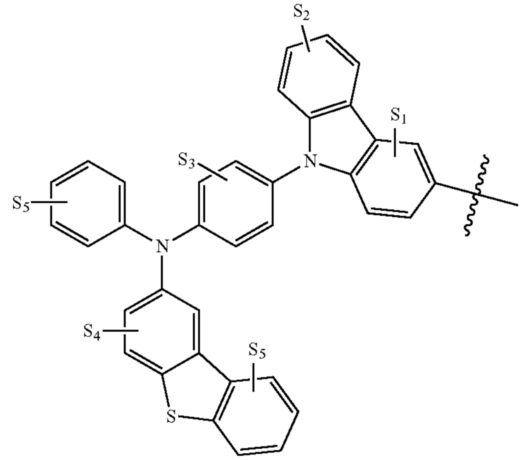

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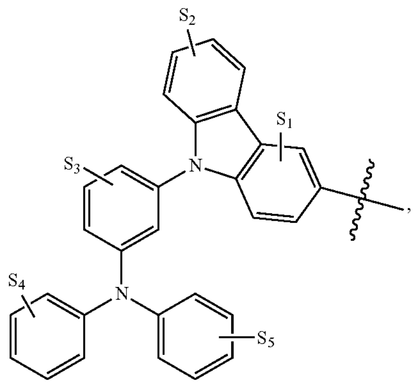

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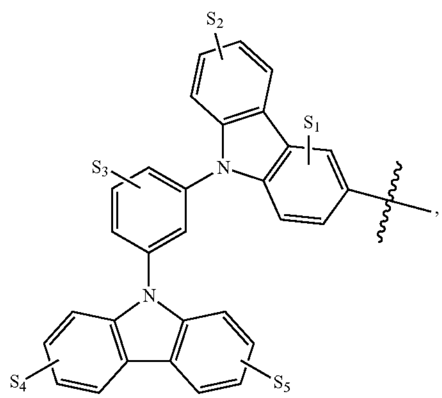

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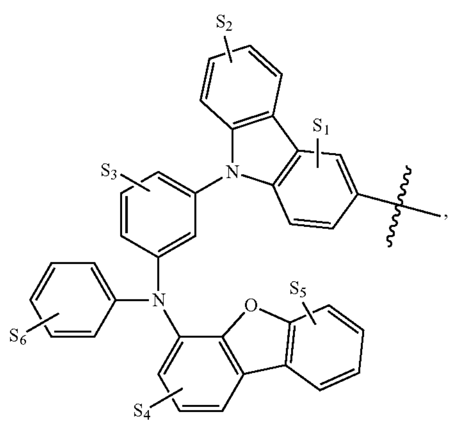

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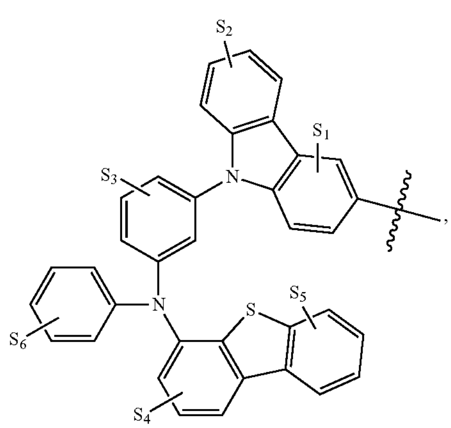

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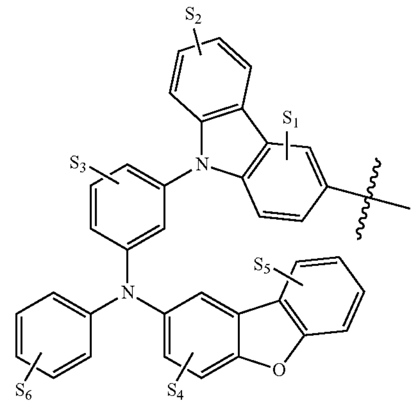

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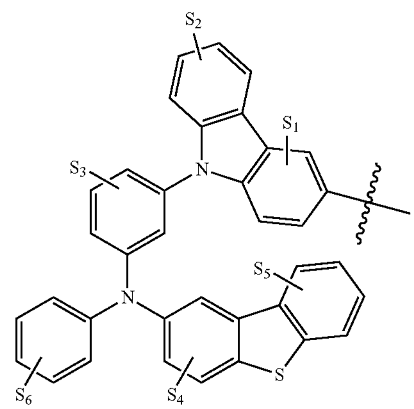

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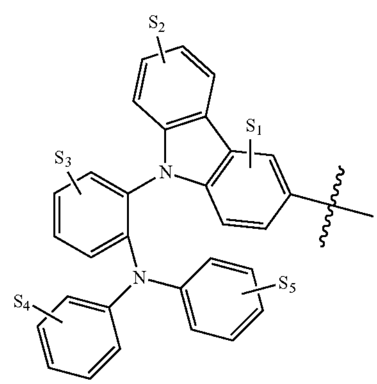

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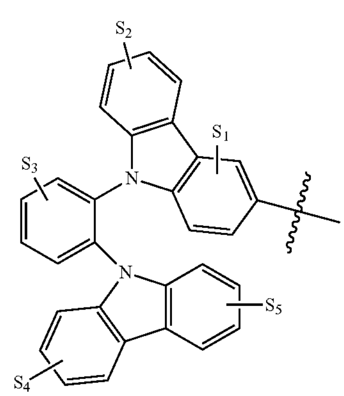

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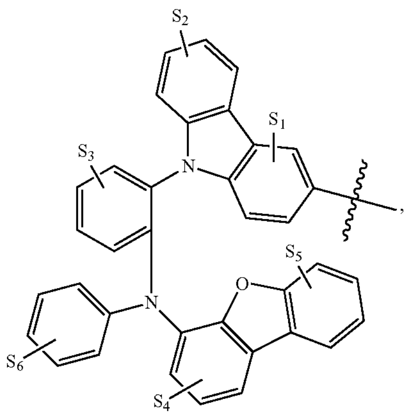
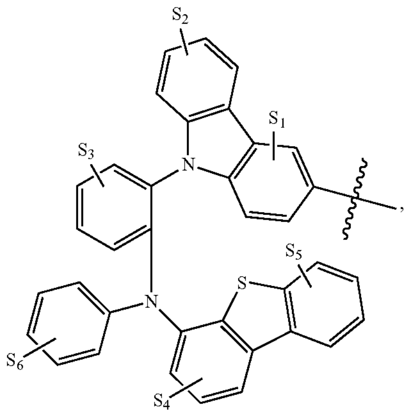
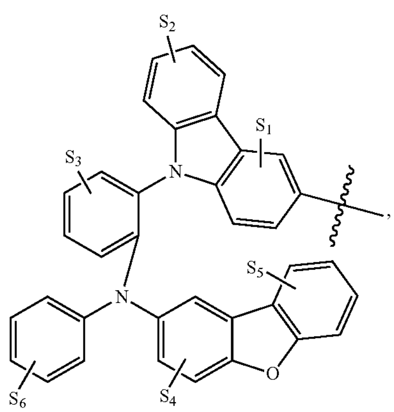


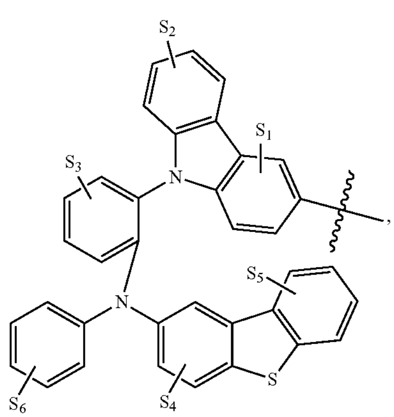
D138



D139



D140



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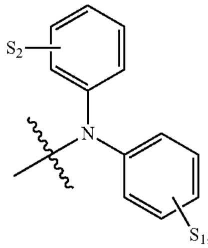
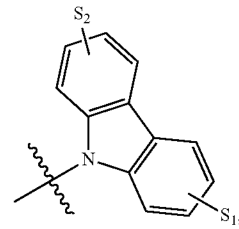
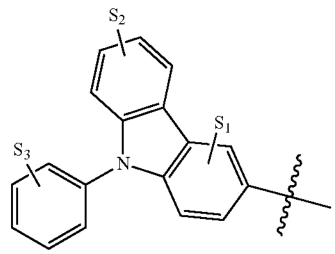
D141



D142

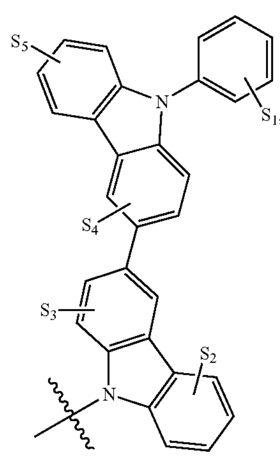


D143



and

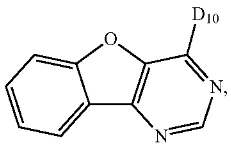
D144



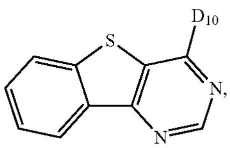
wherein S_1 to S_7 represent mono, di, tri, tetra or penta substitutions with hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrile, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof.

In one embodiment of the first device, the first emitting compound is selected from the group consisting of:

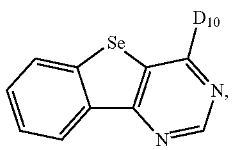
Compound O-10-10



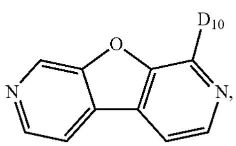
Compound S-10-10



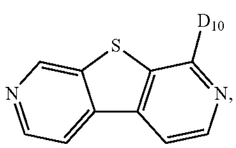
Compound Se-10-10



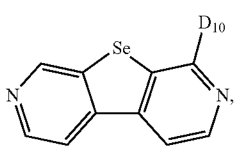
Compound O-13-10



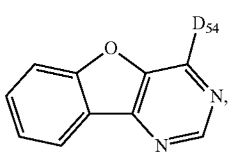
Compound S-13-10



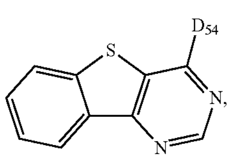
Compound Se-13-10



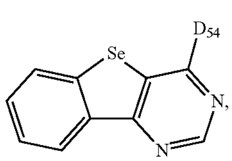
Compound O-10-54



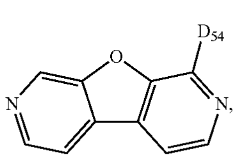
Compound S-10-54



Compound Se-10-54



Compound O-13-54



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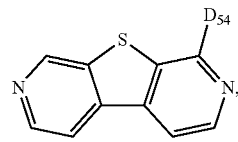
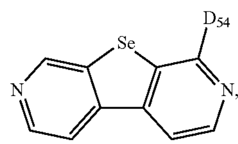
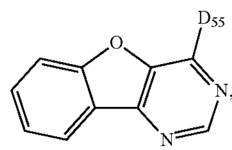
Compound S-13-54



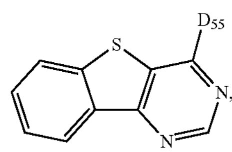
Compound Se-13-54



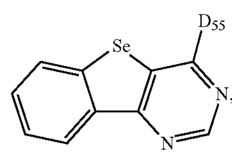
Compound O-10-55



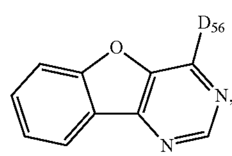
Compound S-10-55



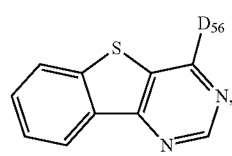
Compound Se-10-55



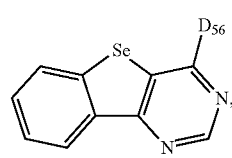
Compound O-10-56



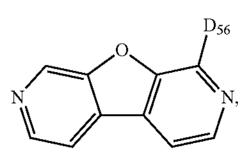
Compound S-10-56



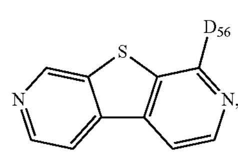
Compound Se-10-56



Compound O-13-56



Compound S-13-56



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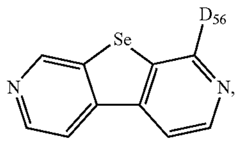
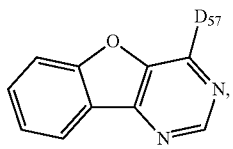
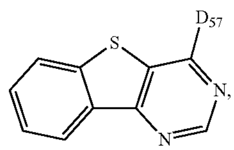
Compound Se-13-56



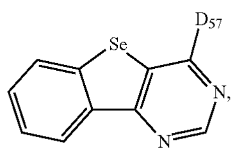
Compound O-10-57



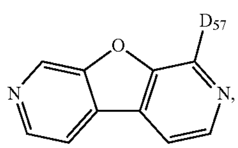
Compound S-10-57



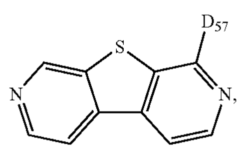
Compound Se-10-57



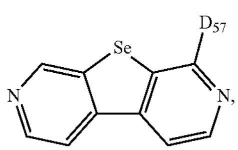
Compound O-13-57



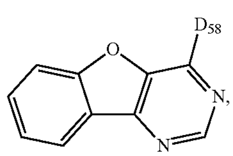
Compound S-13-57



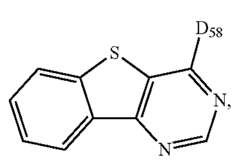
Compound Se-13-57



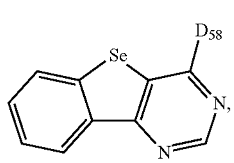
Compound O-10-58



Compound S-10-58



Compound Se-10-58



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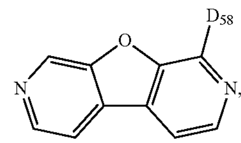
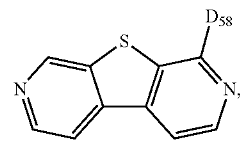
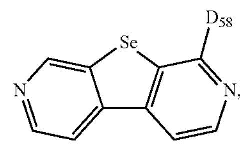
Compound O-13-58



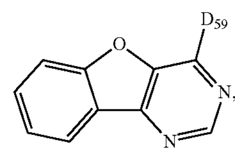
Compound S-13-58



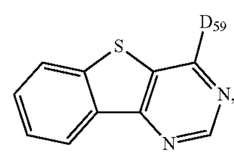
Compound Se-13-58



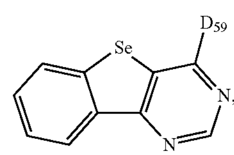
Compound O-10-59



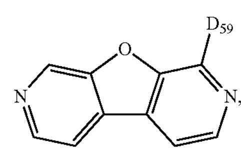
Compound S-10-59



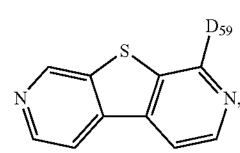
Compound Se-10-59



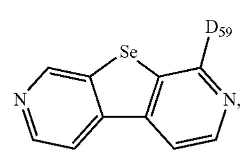
Compound O-13-59



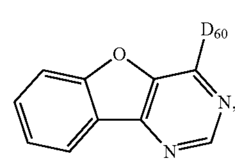
Compound S-13-59



Compound Se-13-59



Compound O-10-60



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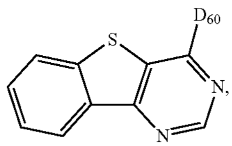
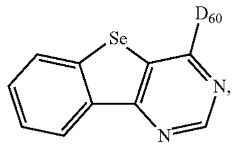
Compound S-10-60



Compound Se-10-60



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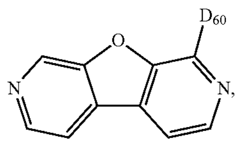
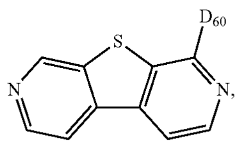
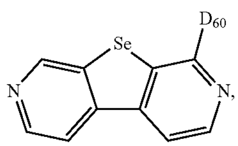


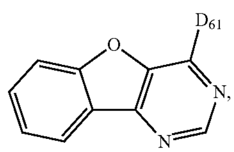
Compound S-13-60



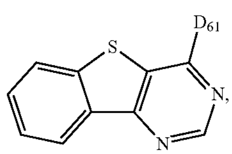
Compound Se-13-60



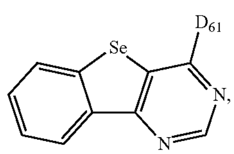
Compound O-10-61



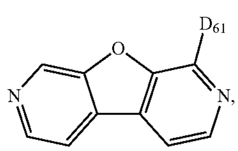
Compound S-10-61



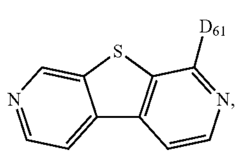
Compound Se-10-61



Compound O-13-61



Compound S-13-61



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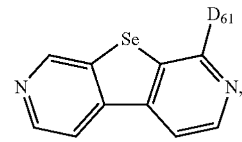
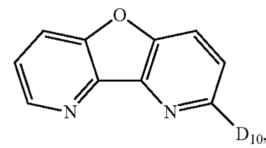
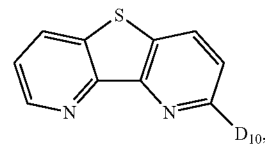
Compound Se-13-61



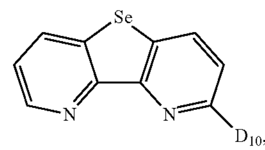
Compound O-17-10



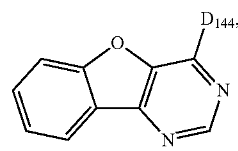
Compound S-17-10



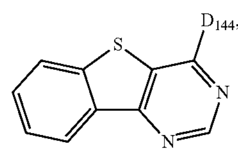
Compound Se-17-10



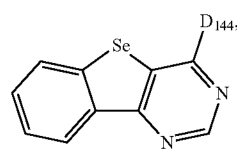
Compound O-10-144



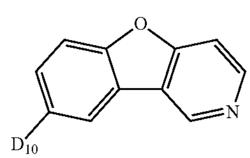
Compound S-10-144



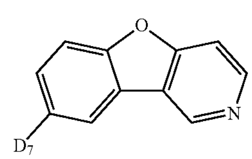
Compound Se-10-144



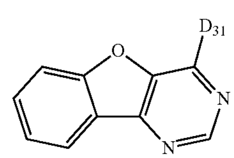
Compound O-20-10



Compound O-20-7



Compound O-10-31



and

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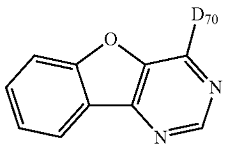
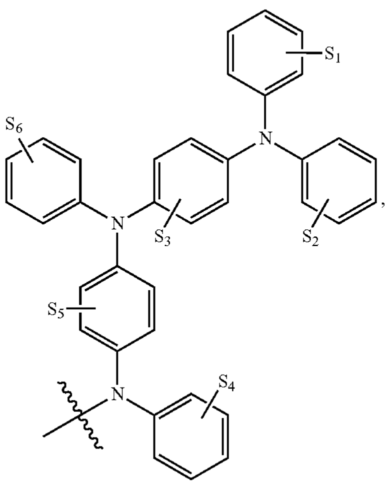
Compound O-10-70

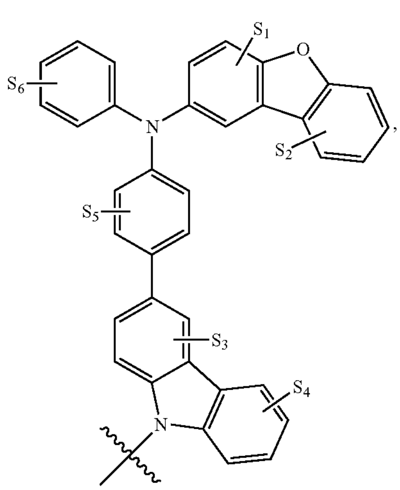


wherein in D7, D10, D31, D54, D55, D56, D57, D58, D59, D60, D61, D70 and D144 are

D7



D10



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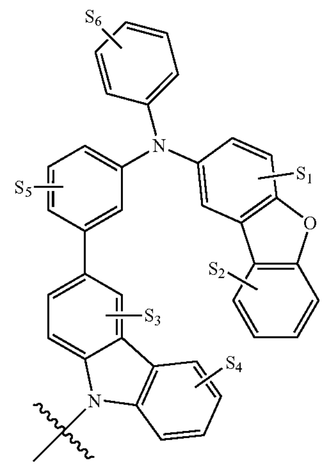
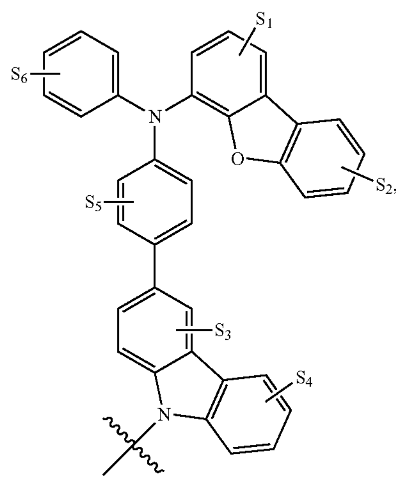
D31



D54



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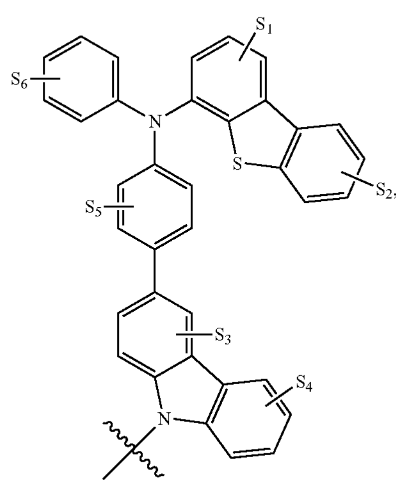

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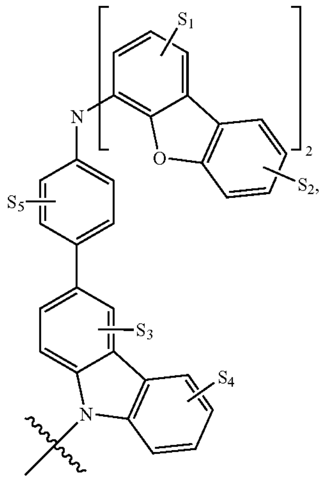
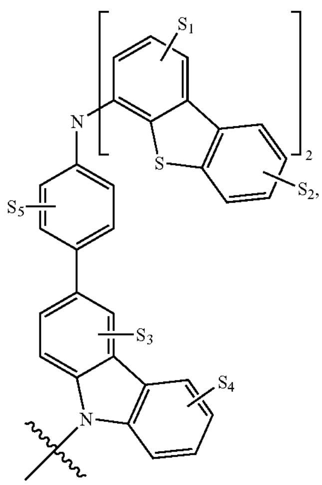
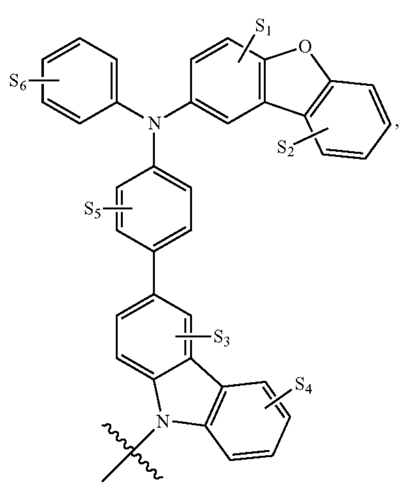
D56



D57



D58



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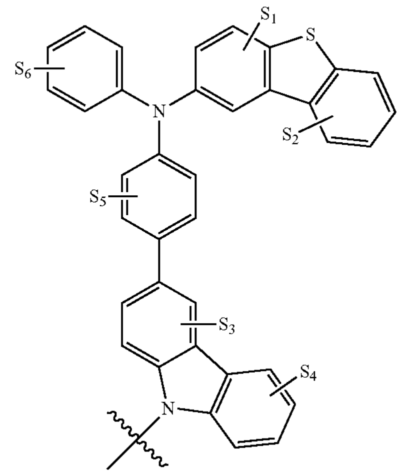
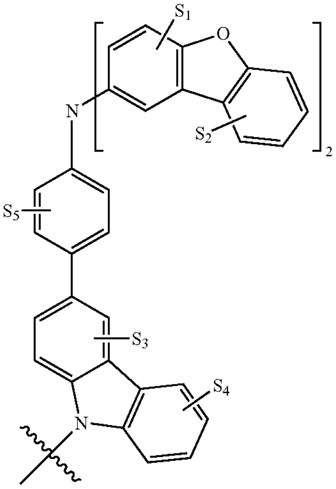
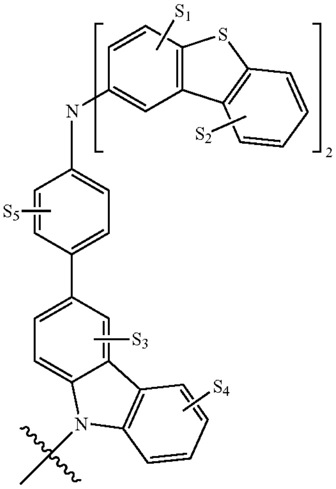
D59



D60



D61



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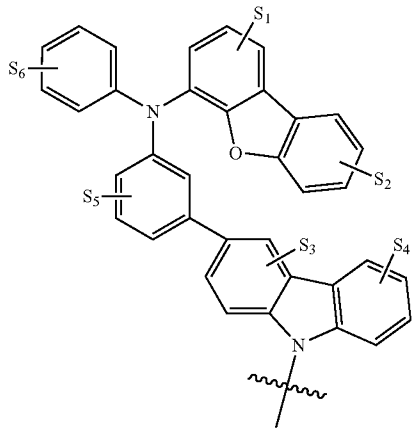
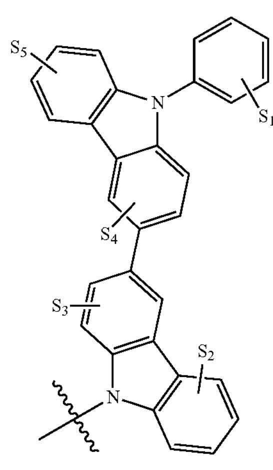
D70



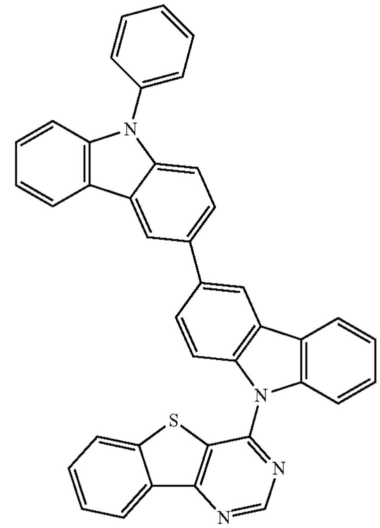
and

D144



wherein S_1 to S_6 represent mono, di, tri, tetra or penta substitutions with hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrile, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof. In another embodiment of the first device, S_1 to S_6 are H. The resulting compounds are denoted as Compound No.-H. For example, Compound S-10-144-H is

Compound S-10-144-H



The first device emits a luminescent radiation at room temperature when a voltage is applied across the organic light emitting device, wherein the luminescent radiation comprises a delayed fluorescence process. In the first device, the emissive layer can further comprise a first phosphorescent emitting material. In other embodiments, the emissive layer further comprises a second phosphorescent emitting material. The emissive layer further comprises a host material.

According to another aspect of the present disclosure, the first device comprises a second organic light emitting device, wherein the second organic light emitting device is stacked on the first organic light emitting device. The first device can be a consumer product. The first device can be an organic light-emitting device. The first device can be a lighting panel.

According to another embodiment of the first device, at least one of the R comprises a donor group with at least two electron-donating nitrogens.

In yet another aspect of the present disclosure, a formulation that includes a compound according to Formula 1 is described. The formulation can include one or more components selected from the group consisting of a solvent, a host, a hole injection material, hole transport material, an electron transport layer material (see below).

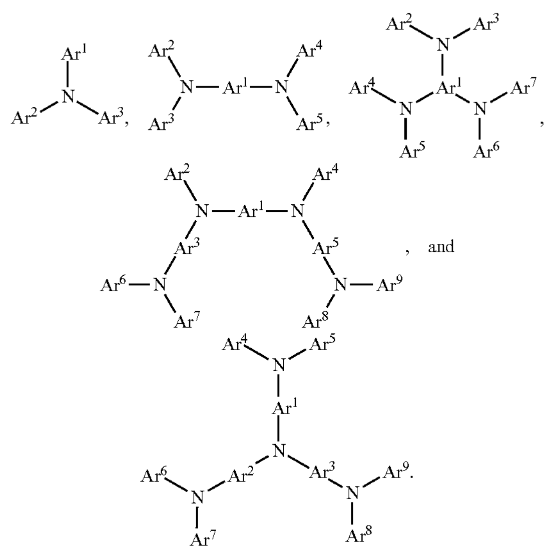
Combination with Other Materials

The materials described herein as useful for a particular layer in an organic light emitting device may be used in combination with a wide variety of other materials present in the device. For example, emissive dopants disclosed herein may be used in conjunction with a wide variety of hosts, transport layers, blocking layers, injection layers, electrodes and other layers that may be present. The materials described or referred to below are non-limiting examples of materials that may be useful in combination with the compounds disclosed herein, and one of skill in the art can readily consult the literature to identify other materials that may be useful in combination.

HIL/HTL:

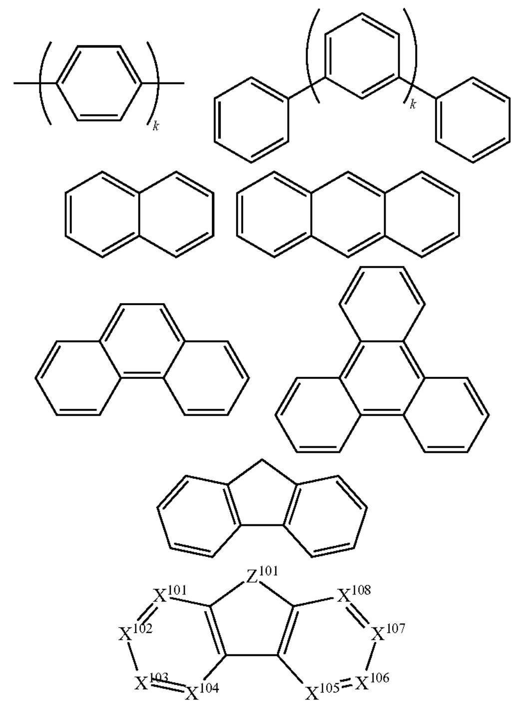
A hole injecting/transporting material to be used in the present invention is not particularly limited, and any compound may be used as long as the compound is typically used as a hole injecting/transporting material. Examples of the material include, but not limit to: a phthalocyanine or porphryin derivative; an aromatic amine derivative; an indolocarbazole derivative; a polymer containing fluorohydrocarbon; a polymer with conductivity dopants; a conducting polymer, such as PEDOT/PSS; a self-assembly monomer derived from compounds such as phosphonic acid and sliane derivatives; a metal oxide derivative, such as MoO_x; a p-type semiconducting organic compound, such as 1,4,5,8,9,12-Hexaazatriphenylenehexacarbonitrile; a metal complex, and a cross-linkable compounds.

Examples of aromatic amine derivatives used in HIL or HTL include, but not limit to, the following general structures:



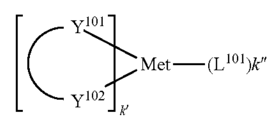
Each of Ar^1 to Ar^9 is selected from the group consisting aromatic hydrocarbon cyclic compounds such as benzene, biphenyl, triphenyl, triphenylene, naphthalene, anthracene, phenalene, phenanthrene, fluorene, pyrene, chrysene, perylene, azulene; group consisting aromatic heterocyclic compounds such as dibenzothiophene, dibenzofuran, dibenzoselenophene, furan, thiophene, benzofuran, benzothiophene, benzoselenophene, carbazole, indolocarbazole, pyridylindole, pyrrolodipyridine, pyrazole, imidazole, triazole, oxazole, thiazole, oxadiazole, oxatriazole, dioxazole, thiadiazole, pyridine, pyridazine, pyrimidine, pyrazine, triazine, oxazine, oxathiazine, oxadiazine, indole, benzimidazole, indazole, indoxazine, benzoxazole, benzisoxazole, benzothiazole, quinoline, isoquinoline, cinnoline, quinazoline, quinoxaline, naphthyridine, phthalazine, pteridine, xanthene, acridine, phenazine, phenothiazine, phenoxazine, benzofuropyridine, furodipyridine, benzothienopyridine, thienodipyridine, benzoselenophenopyridine, and selenophenodipyridine; and group consisting 2 to 10 cyclic structural units which are groups of the same type or different types selected from the aromatic hydrocarbon cyclic group and the aromatic heterocyclic group and are bonded to each other directly or via at least one of oxygen atom, nitrogen atom, sulfur atom, silicon atom, phosphorus atom, boron atom, chain structural unit and the aliphatic cyclic group. Wherein each Ar is further substituted by a substituent selected from the group consisting of hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrile, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof.

In one aspect, Ar^1 to Ar^9 is independently selected from the group consisting of:



k is an integer from 1 to 20; X^{101} to X^{108} is C (including CH) or N; Z^{101} is NAr^1, O, or S; Ar^1 has the same group defined above.

Examples of metal complexes used in HIL or HTL include, but not limit to the following general formula:



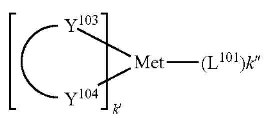
Met is a metal, which can have an atomic weight greater than 40; (Y^{101}-Y^{102}) is a bidentate ligand, Y^{101} and Y^{102} are independently selected from C, N, O, P, and S; L^{101} is an ancillary ligand; k' is an integer value from 1 to the maximum number of ligands that may be attached to the metal; and k'+k" is the maximum number of ligands that may be attached to the metal.

In one aspect, (Y^{101}-Y^{102}) is a 2-phenylpyridine derivative. In another aspect, (Y^{101}-Y^{102}) is a carbene ligand. In another aspect, Met is selected from Ir, Pt, Os, and Zn. In a further aspect, the metal complex has a smallest oxidation potential in solution vs. Fc^+/Fc couple less than about 0.6 V.

Host:

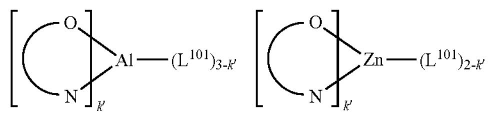
The light emitting layer of the organic EL device of the present invention preferably contains at least a metal complex as light emitting material, and may contain a host material using the metal complex as a dopant material. Examples of the host material are not particularly limited, and any metal complexes or organic compounds may be used as long as the triplet energy of the host is larger than that of the dopant. While the Table below categorizes host materials as preferred for devices that emit various colors, any host material may be used with any dopant so long as the triplet criteria is satisfied.

Examples of metal complexes used as host are preferred to have the following general formula:



wherein Met is a metal; (Y^{103}-Y^{104}) is a bidentate ligand, Y^{103} and Y^{104} are independently selected from C, N, O, P, and S; L^{101} is an another ligand; k' is an integer value from 1 to the maximum number of ligands that may be attached to the metal; and k'+k" is the maximum number of ligands that may be attached to the metal.

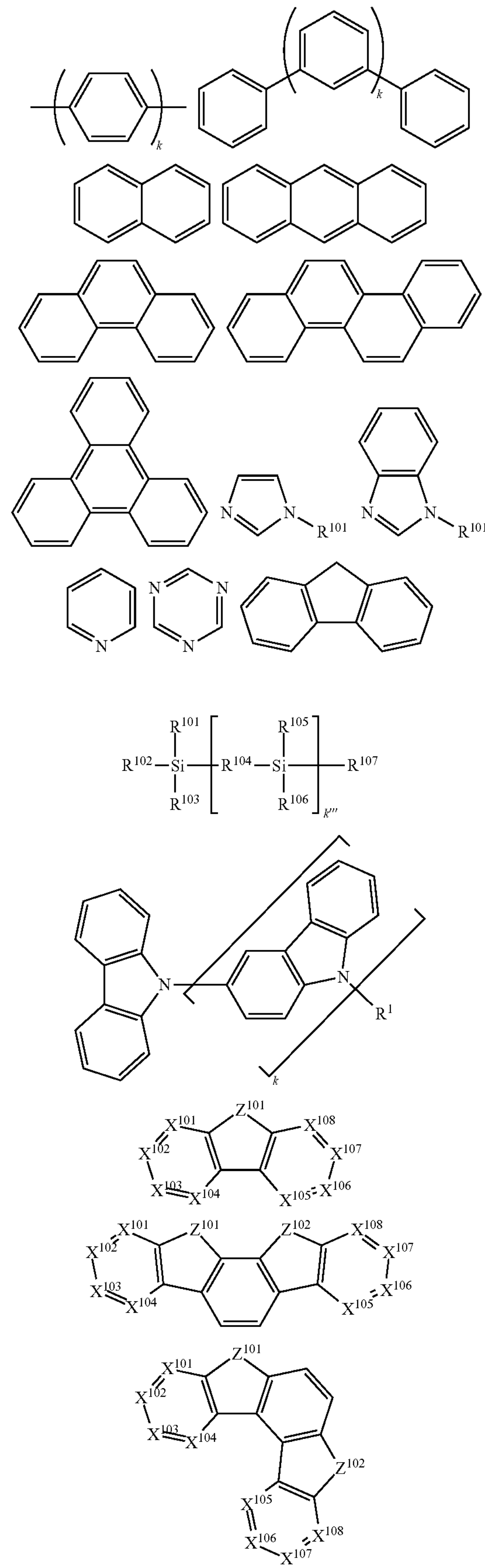
In one aspect, the metal complexes are:



wherein (O—N) is a bidentate ligand, having metal coordinated to atoms O and N. In another aspect, Met is selected from Ir and Pt. In a further aspect, (Y^{103}-Y^{104}) is a carbene ligand.

Examples of organic compounds used as host are selected from the group consisting aromatic hydrocarbon cyclic compounds such as benzene, biphenyl, triphenyl, triphenylene, naphthalene, anthracene, phenalene, phenanthrene, fluorene, pyrene, chrysene, perylene, azulene; group consisting aromatic heterocyclic compounds such as dibenzothiophene, dibenzofuran, dibenzoselenophene, furan, thiophene, benzofuran, benzothiophene, benzoselenophene, carbazole, indolocarbazole, pyridylindole, pyrrolodipyridine, pyrazole, imidazole, triazole, oxazole, thiazole, oxadiazole, oxatriazole, dioxazole, thiadiazole, pyridine, pyridazine, pyrimidine, pyrazine, triazine, oxazine, oxathiazine, oxadiazine, indole, benzimidazole, indazole, indoxazine, benzoxazole, benzisoxazole, benzothiazole, quinoline, isoquinoline, cinnoline, quinazoline, quinoxaline, naphthyridine, phthalazine, pteridine, xanthene, acridine, phenazine, phenothiazine, phenoxazine, benzofuropyridine, furodipyridine, benzothienopyridine, thienodipyridine, benzoselenophenopyridine, and selenophenodipyridine; and group consisting 2 to 10 cyclic structural units which are groups of the same type or different types selected from the aromatic hydrocarbon cyclic group and the aromatic heterocyclic group and are bonded to each other directly or via at least one of oxygen atom, nitrogen atom, sulfur atom, silicon atom, phosphorus atom, boron atom, chain structural unit and the aliphatic cyclic group. Wherein each group is further substituted by a substituent selected from the group consisting of hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrile, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof.

In one aspect, host compound contains at least one of the following groups in the molecule:



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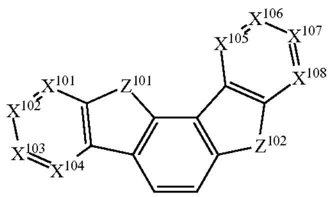
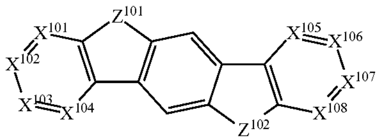
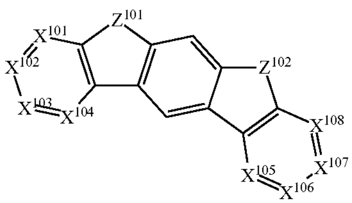






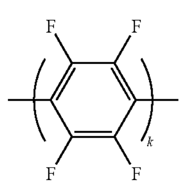
wherein R^{101} to R^{107} is independently selected from the group consisting of hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrile, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof, when it is aryl or heteroaryl, it has the similar definition as Ar's mentioned above. k is an integer from 0 to 20 or 1 to 20; k''' is an integer from 0 to 20. X^{101} to X^{108} is selected from C (including CH) or N; and Z^{101} and Z^{102} is selected from NR^{101}, O, or S.

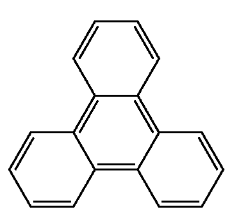
HBL:

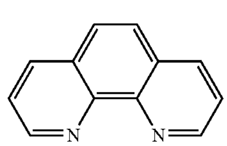
A hole blocking layer (HBL) may be used to reduce the number of holes and/or excitons that leave the emissive layer. The presence of such a blocking layer in a device may result in substantially higher efficiencies as compared to a similar device lacking a blocking layer. Also, a blocking layer may be used to confine emission to a desired region of an OLED.

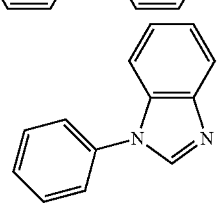
In one aspect, compound used in HBL contains the same molecule or the same functional groups used as host described above.

In another aspect, compound used in HBL contains at least one of the following groups in the molecule:









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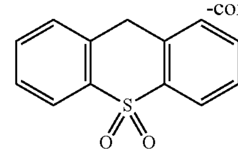
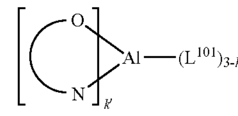


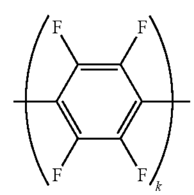


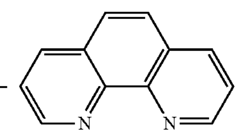
wherein k is an integer from 1 to 20; L^{101} is an another ligand, k' is an integer from 1 to 3.

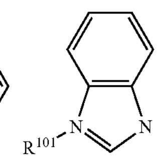
ETL:

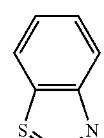
Electron transport layer (ETL) may include a material capable of transporting electrons. Electron transport layer may be intrinsic (undoped), or doped. Doping may be used to enhance conductivity. Examples of the ETL material are not particularly limited, and any metal complexes or organic compounds may be used as long as they are typically used to transport electrons.

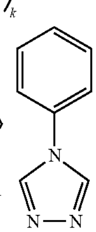
In one aspect, compound used in ETL contains at least one of the following groups in the molecule:

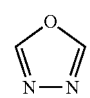


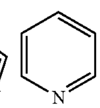


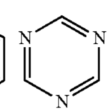


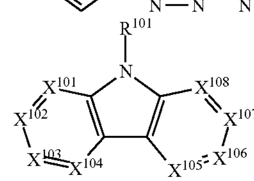


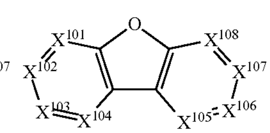


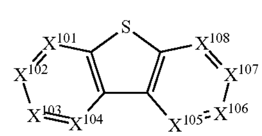


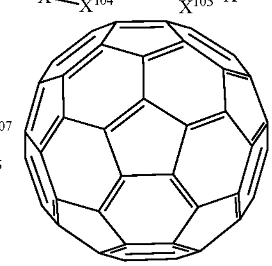


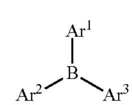






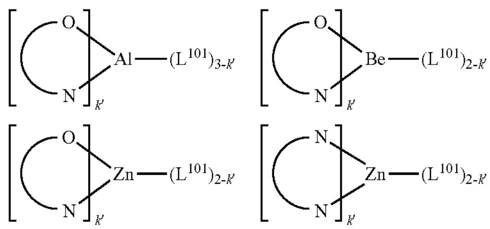






wherein R^{101} is selected from the group consisting of hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrile, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof, when it is aryl or heteroaryl, it has the similar definition as Ar's mentioned above. Ar^1 to Ar^3 has the similar definition as Ar's mentioned above. k is an integer from 1 to 20. X^{101} to X^{108} is selected from C (including CH) or N.

In another aspect, the metal complexes used in ETL contains, but not limit to the following general formula:



wherein (O—N) or (N—N) is a bidentate ligand, having metal coordinated to atoms O, N or N, N; L^{101} is another ligand; k' is an integer value from 1 to the maximum number of ligands that may be attached to the metal.

In any above-mentioned compounds used in each layer of the OLED device, the hydrogen atoms can be partially or fully deuterated. Thus, any specifically listed substituent, such as, without limitation, methyl, phenyl, pyridyl, etc. encompasses undeuterated, partially deuterated, and fully deuterated versions thereof. Similarly, classes of substituents such as, without limitation, alkyl, aryl, cycloalkyl, heteroaryl, etc. also encompass undeuterated, partially deuterated, and fully deuterated versions thereof.

In addition to and/or in combination with the materials disclosed herein, many hole injection materials, hole transporting materials, host materials, dopant materials, exiton/hole blocking layer materials, electron transporting and electron injecting materials may be used in an OLED. Non-limiting examples of the materials that may be used in an OLED in combination with materials disclosed herein are listed in Table 1 below. Table 1 lists non-limiting classes of materials, non-limiting examples of compounds for each class, and references that disclose the materials.

TABLE 1

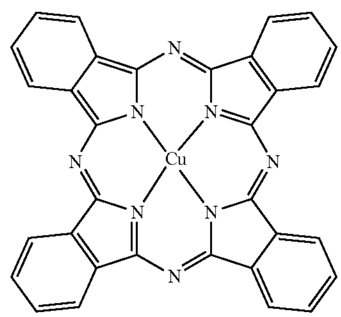
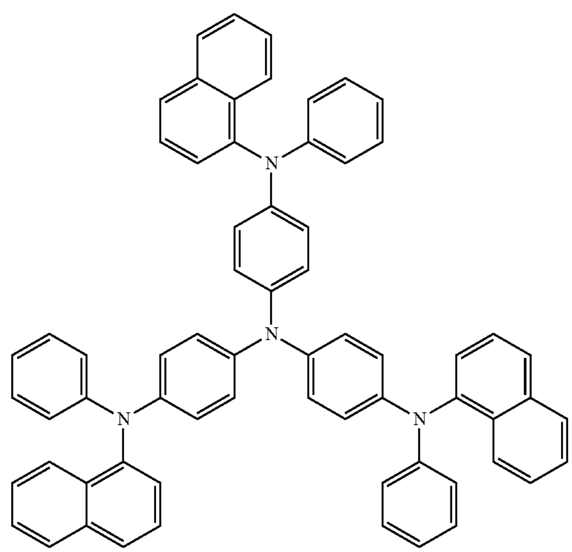
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
	Hole injection materials	
Phthalocyanine and porphryin compounds		Appl. Phys. Lett. 69, 2160 (1996)
Starburst triarylamines		J. Lumin. 72-74, 985 (1997)
CF_x Fluorohydrocarbon polymer	$-\!\!\left[CH_xF_y\right]_n\!\!-$	Appl. Phys. Lett. 78, 673 (2001)

TABLE 1-continued

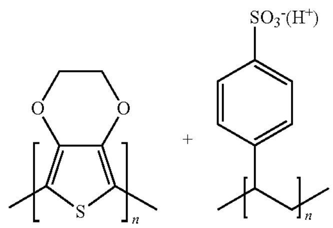
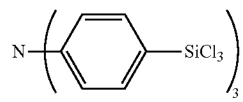
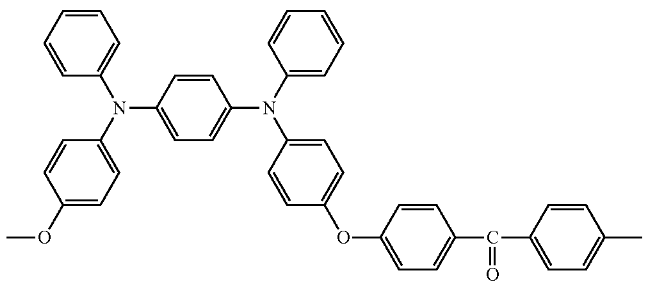
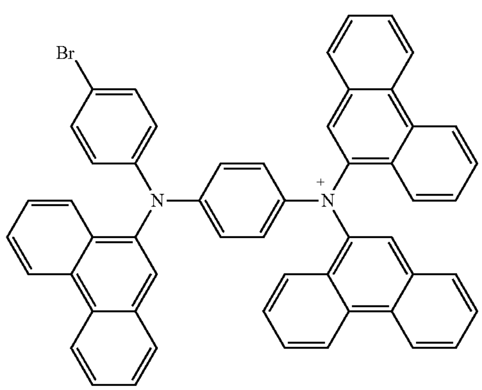
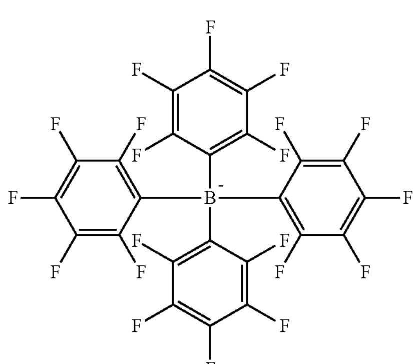
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
	Hole injection materials	
Conducting polymers (e.g., PEDOT:PSS, polyaniline, polypthiophene)		Synth. Met. 87, 171 (1997) WO2007002683
Phosphonic acid and sliane SAMs		US20030162053
Triarylamine or polythiophene polymers with conductivity dopants	 and  	EP1725079A1

TABLE 1-continued

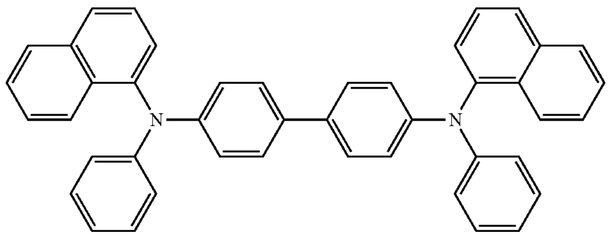
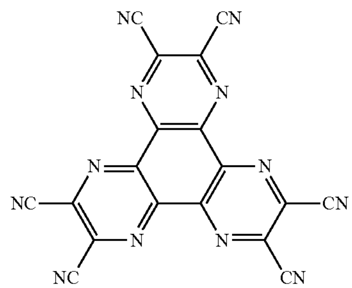
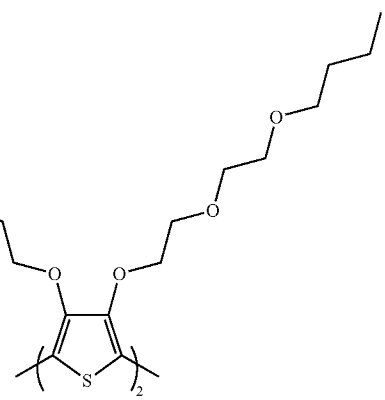
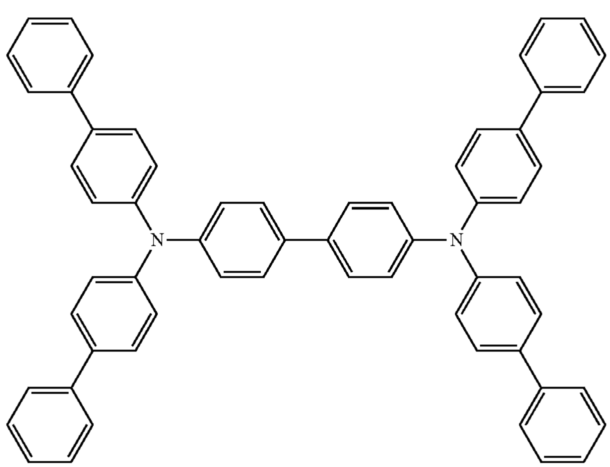
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
	Hole injection materials	
Organic compounds with conductive inorganic compounds, such as molybdenum and tungsten oxides	 + MoO_x	US20050123751 SID Symposium Digest, 37, 923 (2006) WO2009018009
n-type semiconducting organic complexes		US20020158242
Metal organometallic complexes		US20060240279
Cross-linkable compounds		US20080220265
Polythiophene based polymers and copolymers		WO 2011075644 EP2350216
Hole transporting materials		
Triarylamines (e.g., TPD, α-NPD)		Appl. Phys. Lett. 51, 913 (1987) U.S. Pat. No. 5,061,569 EP650955

TABLE 1-continued

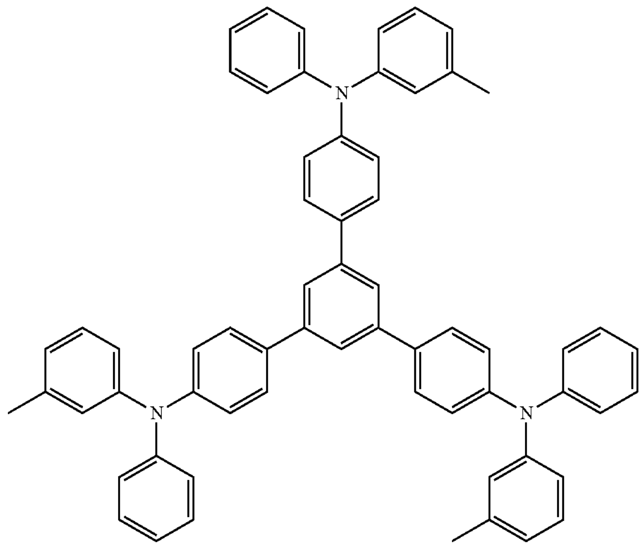
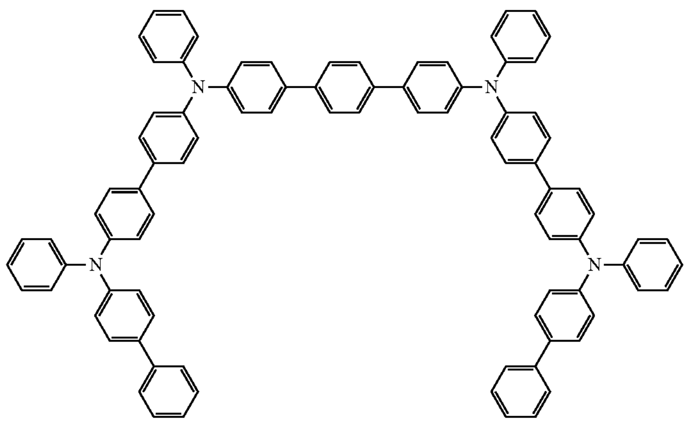
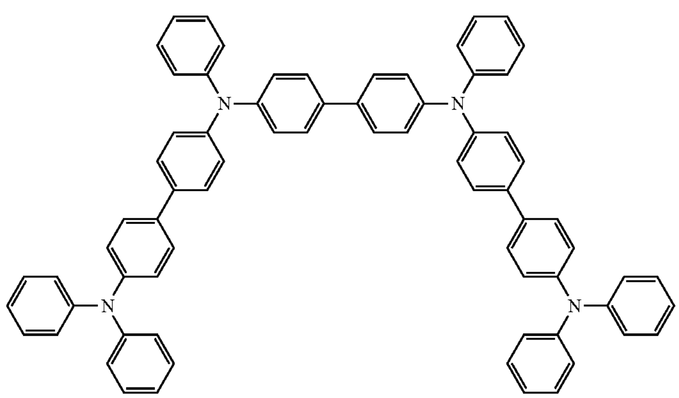
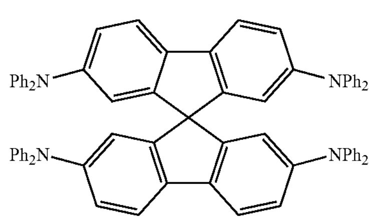
MATERIAL	EXAMPLES OF MATERIAL Hole injection materials	PUBLICATIONS
		J. Mater. Chem. 3, 319 (1993)
		Appl. Phys. Lett. 90, 183503 (2007)
		Appl. Phys. Lett. 90, 183503 (2007)
Triaylamine on spirofluorene core		Synth. Met. 91, 209 (1997)

TABLE 1-continued

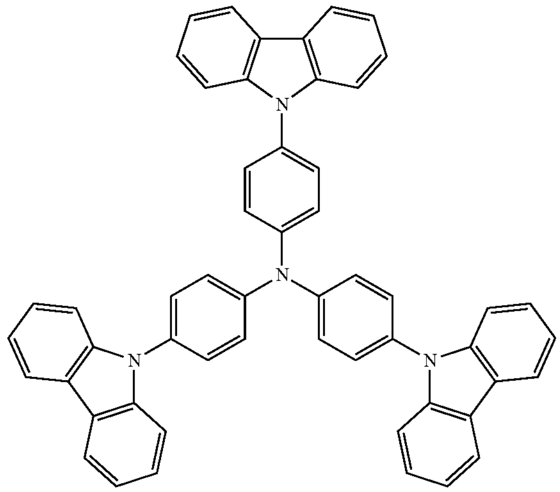
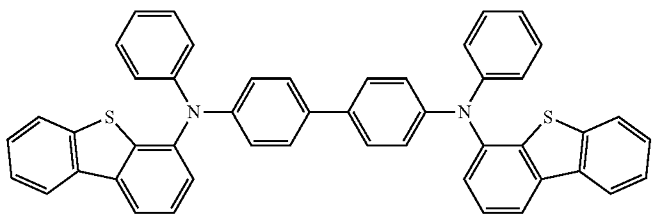
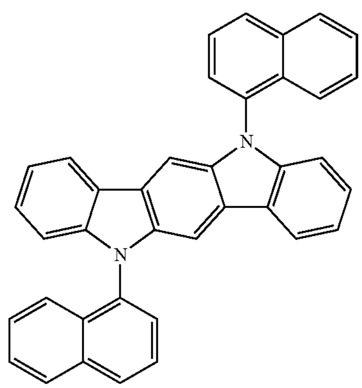
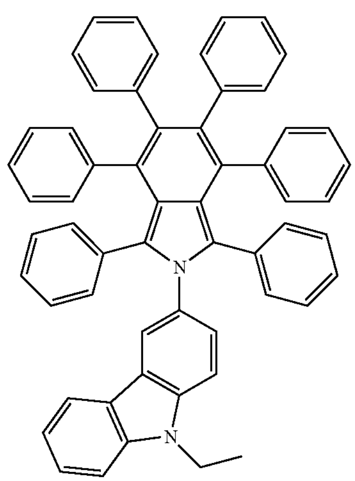
MATERIAL	EXAMPLES OF MATERIAL Hole injection materials	PUBLICATIONS
Arylamine carbazole compounds		Adv. Mater. 6, 677 (1994), US20080124572
Triarylamine with (di)benzothiophene/ (di)benzofuran		US20070278938, US20080106190 US20110163302
Indolocarbazoles		Synth. Met. 111, 421 (2000)
Isoindole compounds		Chem. Mater. 15, 3148 (2003)

TABLE 1-continued

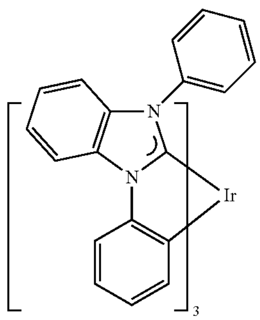
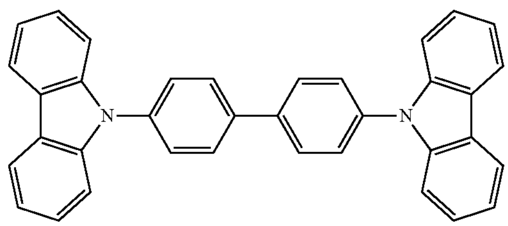
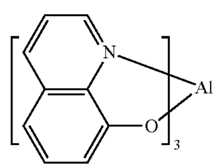
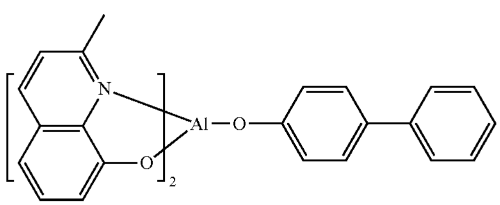
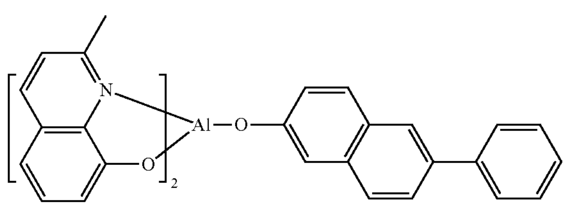
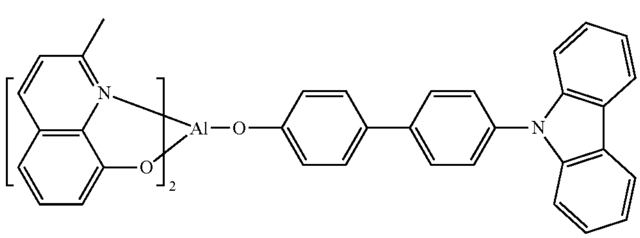
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
	Hole injection materials	
Metal carbene complexes		US20080018221
Phosphorescent OLED host materials Red hosts		
Arylcarbazoles		Appl. Phys. Lett. 78, 1622 (2001)
Metal 8-hydroxyquinolates (e.g., Alq_3, BAlq)		Nature 395, 151 (1998)
		US20060202194
		WO2005014551
		WO2006072002

TABLE 1-continued

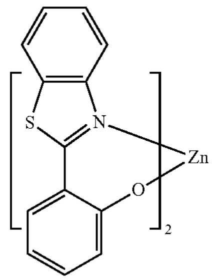
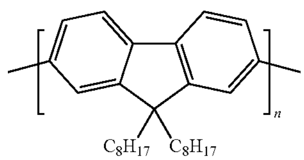
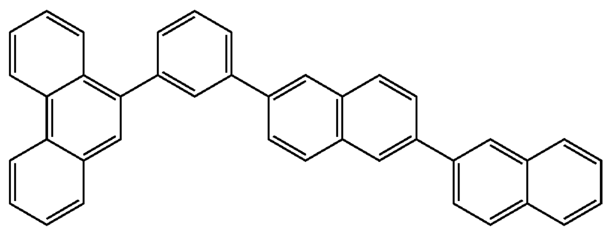
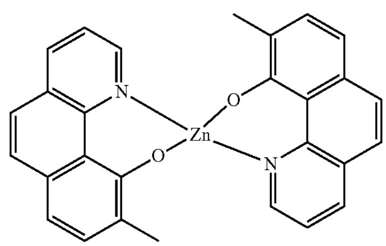
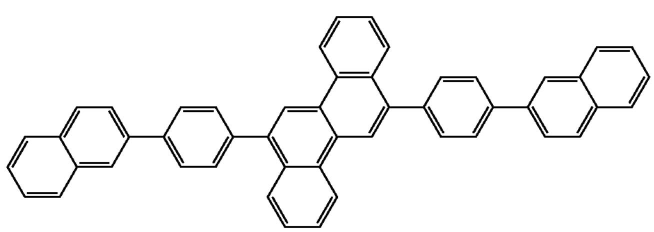
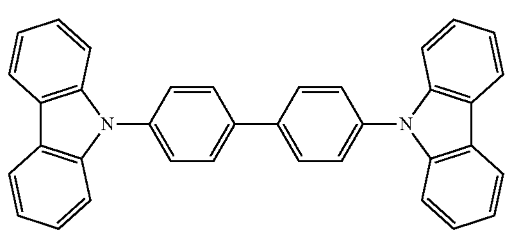
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
	Hole injection materials	
Metal phenoxybenzothiazole compounds		Appl. Phys. Lett. 90, 123509 (2007)
Conjugated oligomers and polymers (e.g., polyfluorene)		Org. Electron. 1, 15 (2000)
Aromatic fused rings		WO2009066779, WO2009066778, WO2009063833, US20090045731, US20090045730, WO2009008311, US20090008605, US20090009065
Zinc complexes		WO2010056066
Chrysene based compounds		WO2011086863
Green hosts		
Arylcarbazoles		Appl. Phys. Lett. 78, 1622 (2001)

TABLE 1-continued

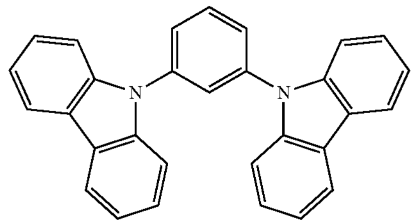
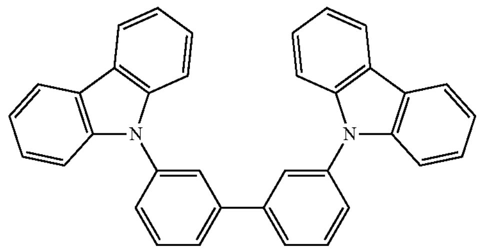
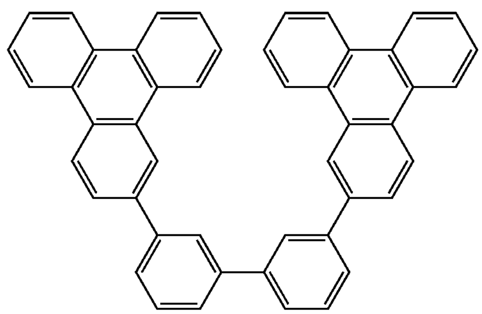
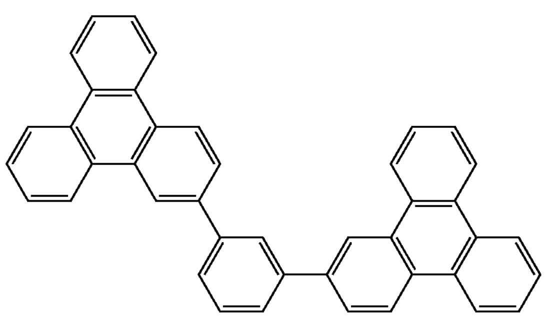
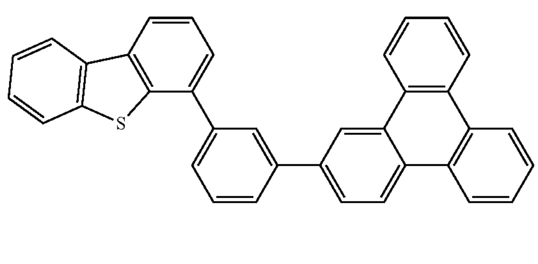
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
	Hole injection materials	
		US20030175553
		WO2001039234
Aryltriphenylene compounds		US20060280965
		US20060280965
		WO2009021126

TABLE 1-continued

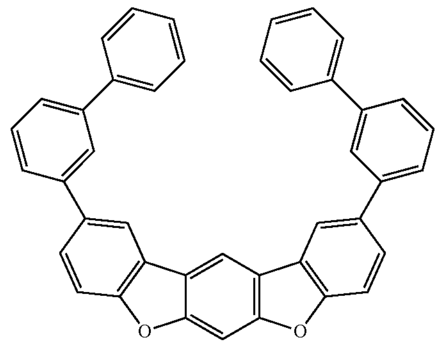
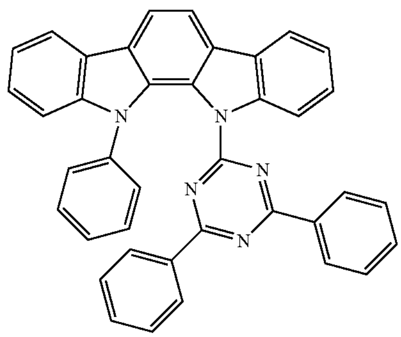
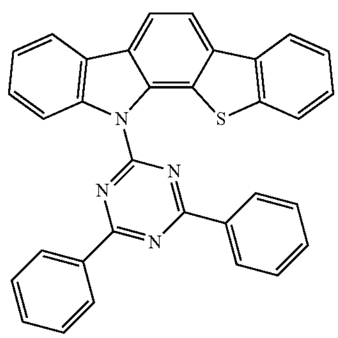
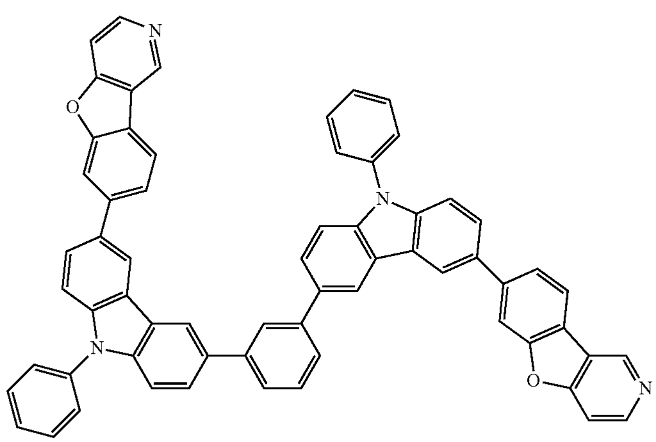
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
	Hole injection materials	
Poly-fused heteroaryl compounds		US20090309488 US20090302743 US20100012931
Donor acceptor type molecules		WO2008056746
		WO2010107244
Aza-carbazole/DBT/DBF		JP2008074939

TABLE 1-continued

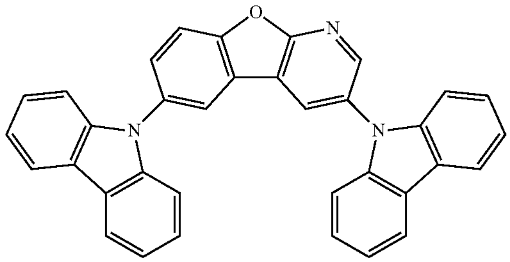
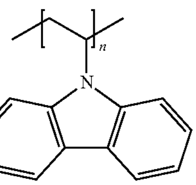
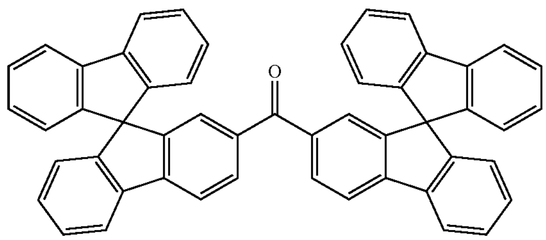
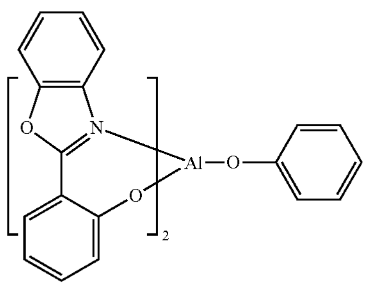
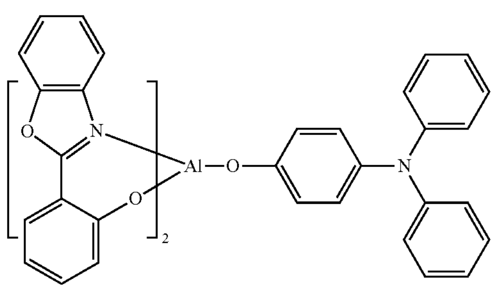
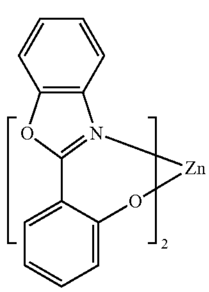
MATERIAL	EXAMPLES OF MATERIAL Hole injection materials	PUBLICATIONS
		US20100187984
Polymers (e.g., PVK)		Appl. Phys. Lett. 77, 2280 (2000)
Spirofluorene compounds		WO2004093207
Metal phenoxybenzooxazole compounds		WO2005089025
		WO2006132173
		JP200511610

TABLE 1-continued

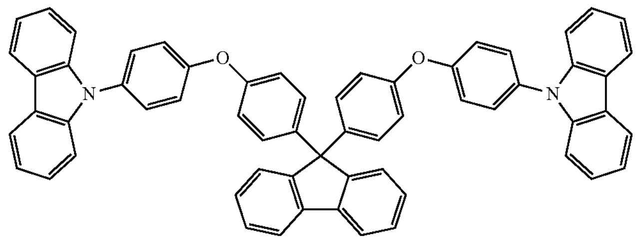
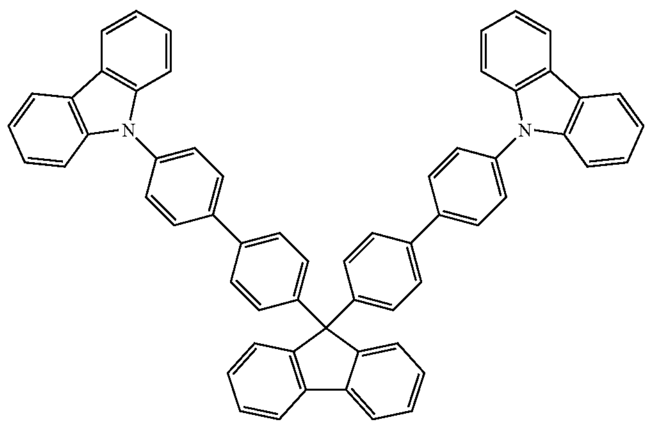
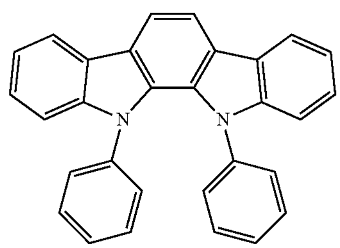
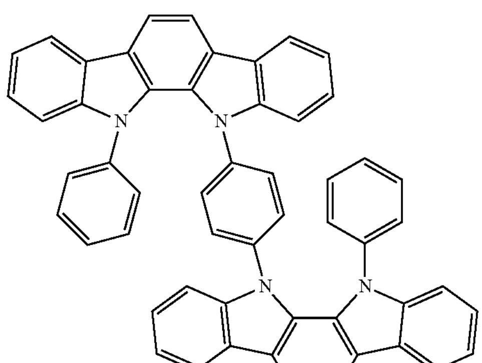
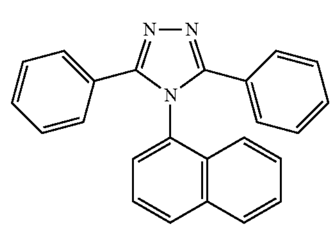
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
	Hole injection materials	
Spirofluorene-carbazole compounds		JP2007254297
		JP2007254297
Indolocabazoles		WO2007063796
		WO2007063754
5-member ring electron deficient heterocycles (e.g., triazole, oxadiazole)		J. Appl. Phys. 90, 5048 (2001)

TABLE 1-continued

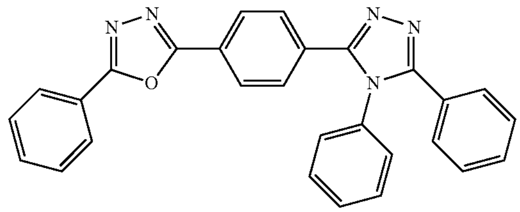
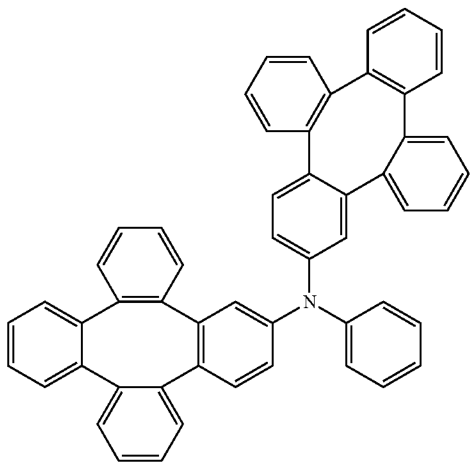
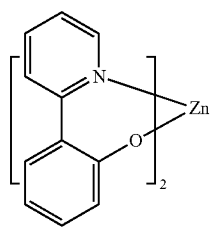
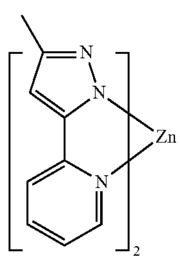
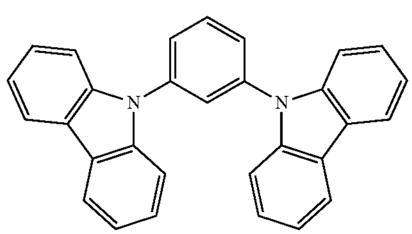
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
	Hole injection materials	
		WO2004107822
Tetraphenylene complexes		US20050112407
Metal phenoxypyridine compounds		WO2005030900
Metal coordination complexes (e.g., Zn, Al with N^N ligands)		US20040137268, US20040137267
Blue hosts		
Arylcarbazoles		Appl. Phys. Lett, 82, 2422 (2003)

TABLE 1-continued

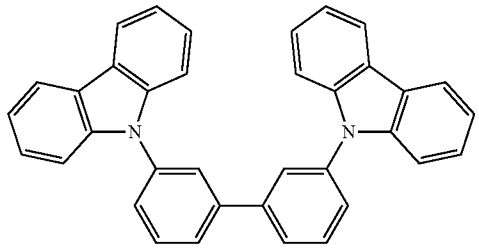
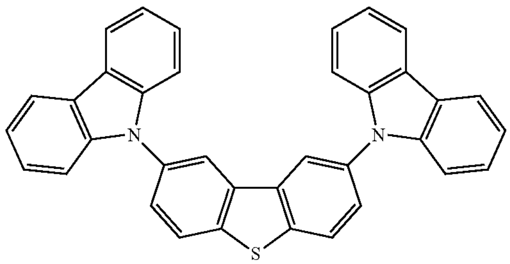
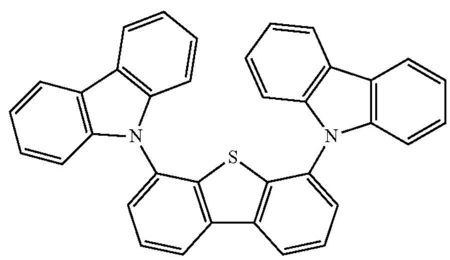
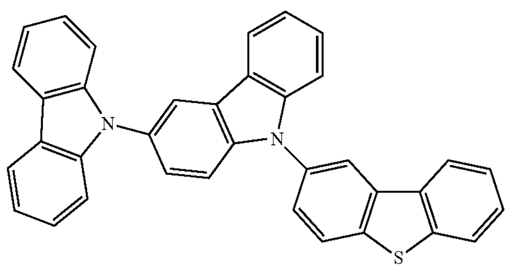
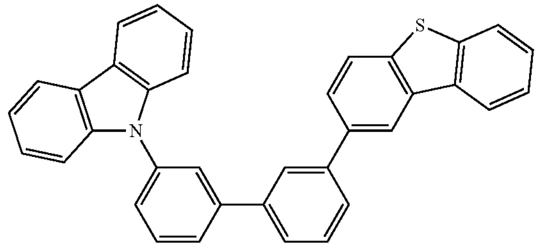
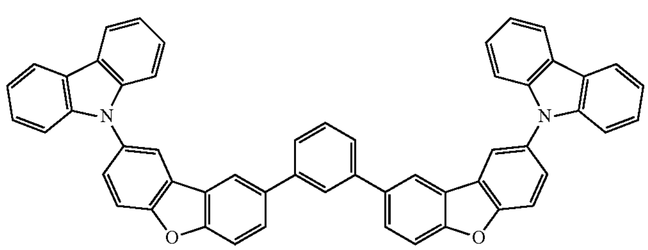
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
	Hole injection materials	
		US20070190359
Dibenzothiophene/ Dibenzofuran-carbazole compounds		WO2006114966, US20090167162
		US20090167162
		WO2009086028
		US20090030202, US20090017330
		US20100084966

TABLE 1-continued

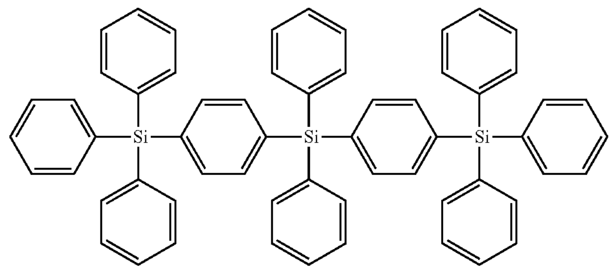
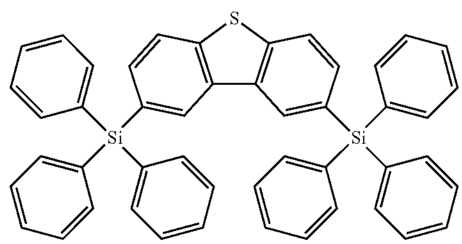
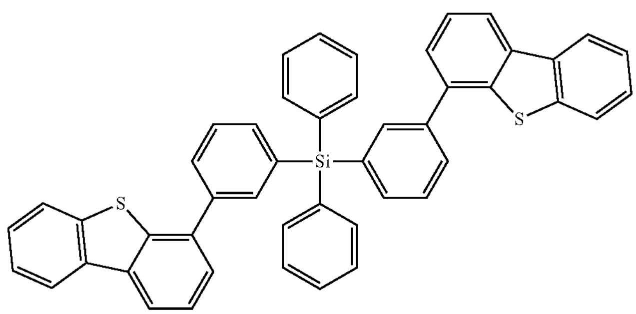
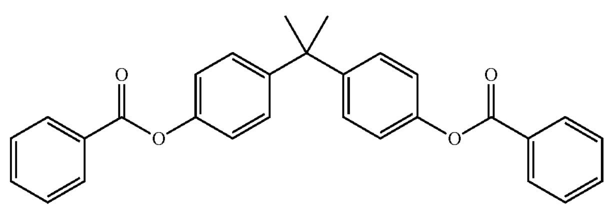
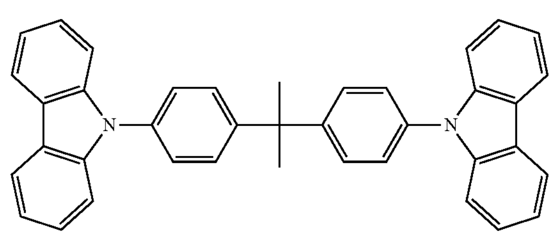
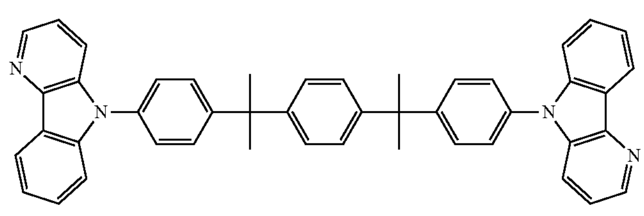
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
	Hole injection materials	
Silicon aryl compounds		US20050238919
		WO2009003898
Silicon/Germanium aryl compounds		EP2034538A
Aryl benzoyl ester		WO2006100298
Carbazole linked by non-conjugated groups		US20040115476
Aza-carbazoles		US20060121308

TABLE 1-continued

MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
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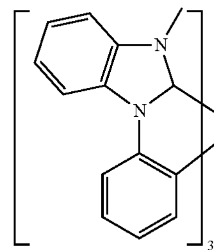
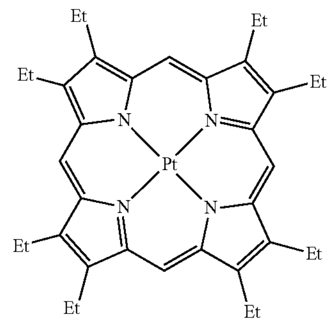
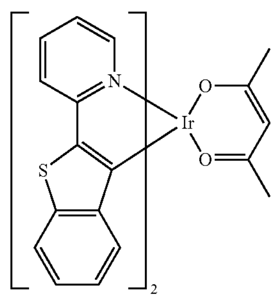
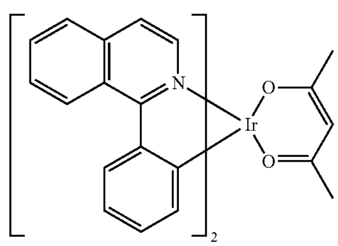
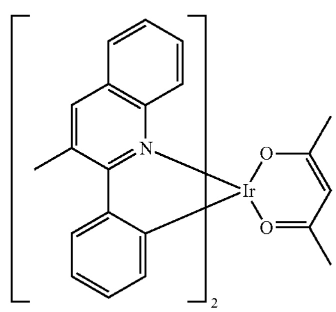
High triplet metal organometallic complex		U.S. Pat. No. 7,154,114
Phosphorescent dopants Red depants		
Heavy metal porphyrins (e.g., PtOEP)		Nature 395, 151 (1998)
Iridium(III) organometallic complexes		Appl. Phys. Lett. 78, 1622 (2001)
		US2006835469
		US2006835469

TABLE 1-continued

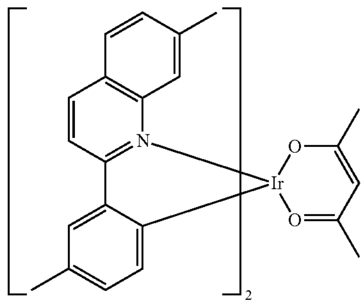
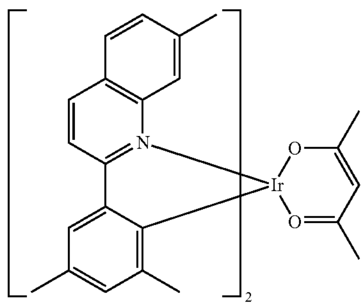
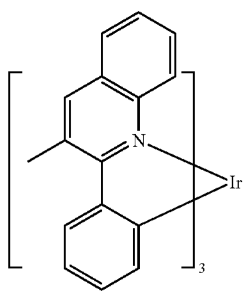
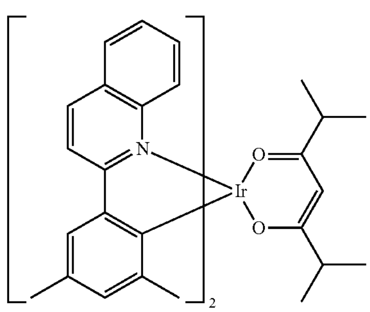
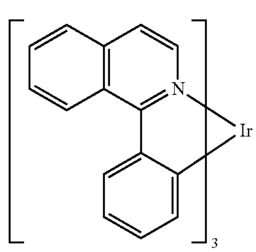
MATERIAL	EXAMPLES OF MATERIAL Hole injection materials	PUBLICATIONS
		US20060202194
		US20060202194
		US20070087321
		US20080261076 US20100090591
		US20070087321

TABLE 1-continued

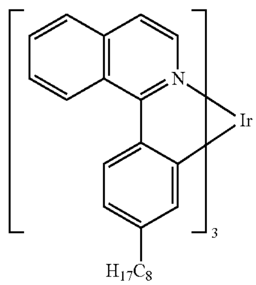
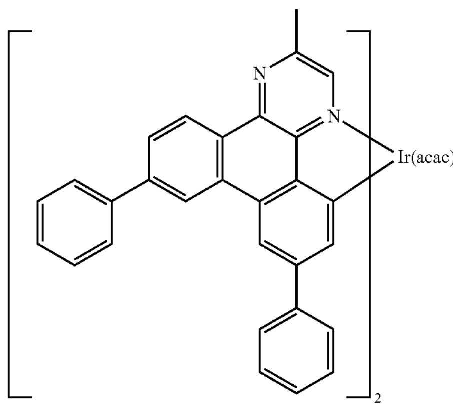
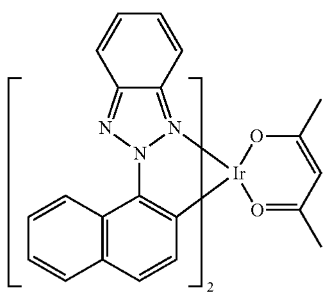
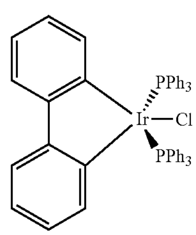
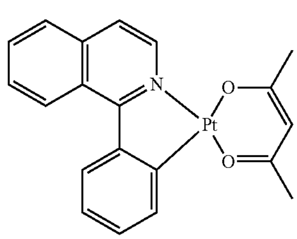
MATERIAL	EXAMPLES OF MATERIAL Hole injection materials	PUBLICATIONS
		Adv. Mater. 19, 739 (2007)
		WO2009100991
		WO2008101842
		U.S. Pat. No. 7,232,618
Platinum(II) organometallic complexes		WO2003040257

TABLE 1-continued

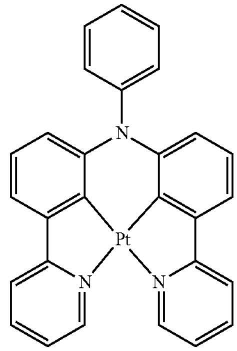
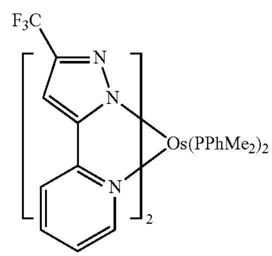
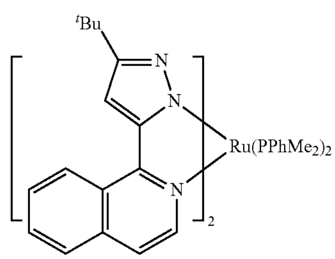
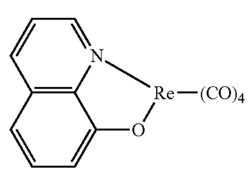
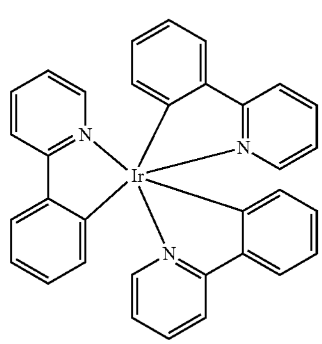
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
	Hole injection materials	
		US20070103060
Osminum(III) complexes		Chem. Mater. 17, 3532 (2005)
Ruthenium(II) complexes		Adv. Mater. 17, 1059 (2005)
Rhenium (I), (II), and (III) complexes		US20050244673
Green dopants		
Iridium(III) organometallic complexes	 and its derivatives	Inorg. Chem. 40, 1704 (2001)

TABLE 1-continued

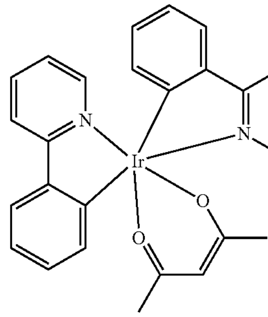
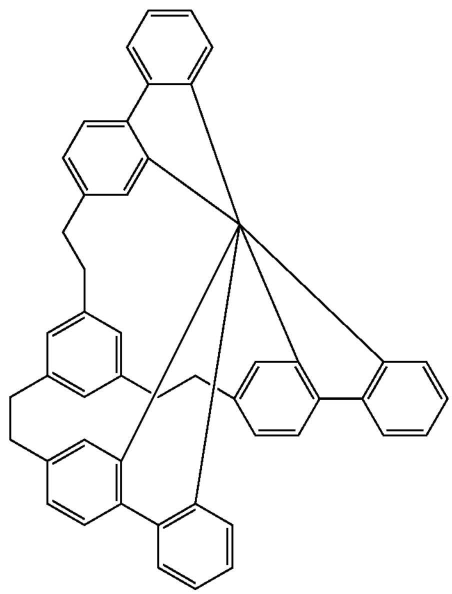
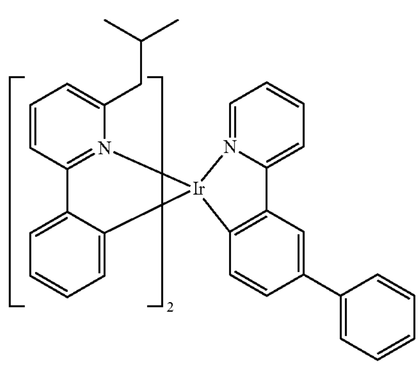
MATERIAL	EXAMPLES OF MATERIAL Hole injection materials	PUBLICATIONS
		US20020034656
		U.S. Pat. No. 7,332,232
		US20090108737

TABLE 1-continued

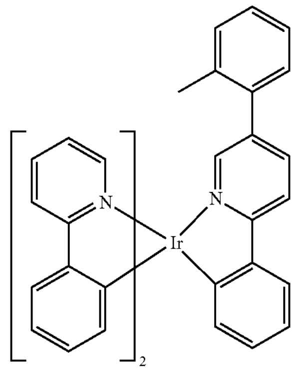
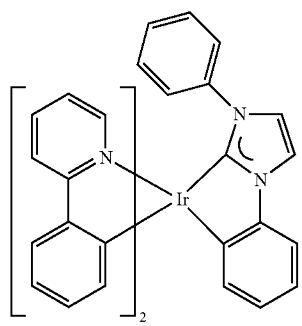
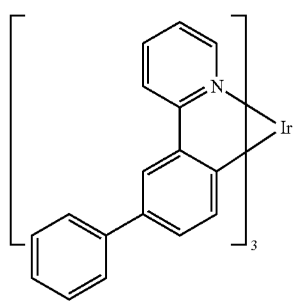
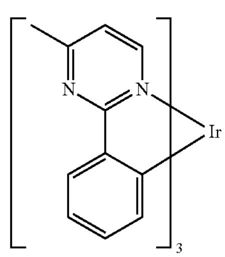
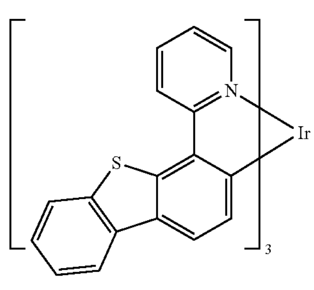
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
	Hole injection materials	
		WO2010028151
		EP1841834B
		US20060127696
		US20090039776
		U.S. Pat. No. 6,921,915

TABLE 1-continued

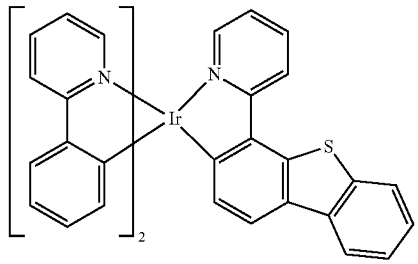
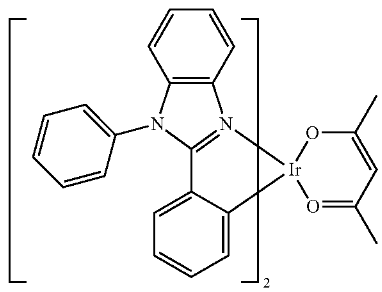
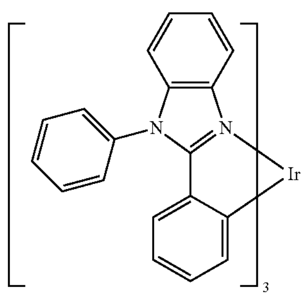
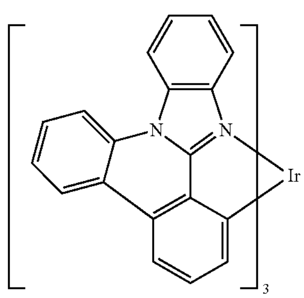
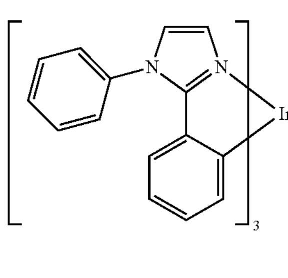
MATERIAL	EXAMPLES OF MATERIAL Hole injection materials	PUBLICATIONS
		US20100244004
		U.S. Pat. No. 6,687,266
		Chem. Mater. 16, 2480 (2004)
		US20070190359
		US 20060008670 JP2007123392

TABLE 1-continued

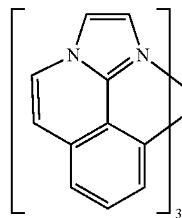
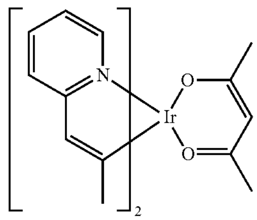
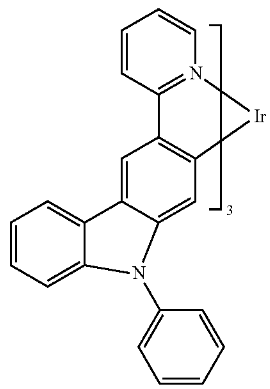
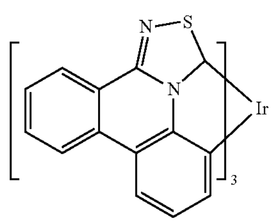
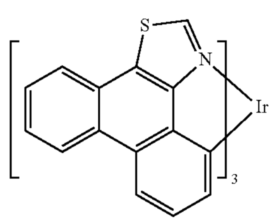
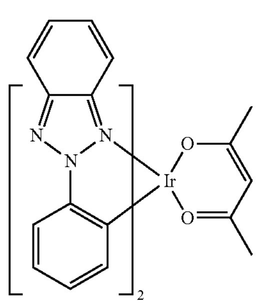
MATERIAL	EXAMPLES OF MATERIAL Hole injection materials	PUBLICATIONS
		WO2010086089, WO2011044988
		Adv. Mater. 16, 2003 (2004)
		Angew. Chem. Int. Ed. 2006, 45, 7800
		WO2009050290
		US20090165846
		US20080015355

TABLE 1-continued

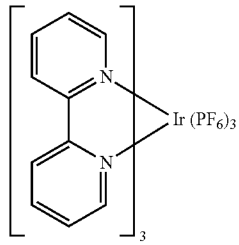
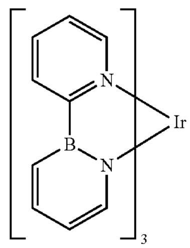
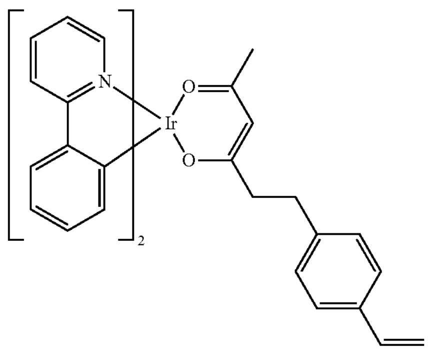
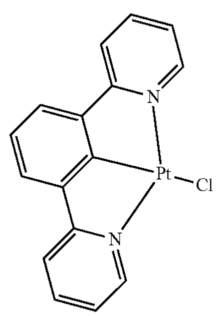
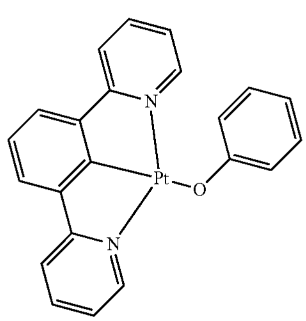
MATERIAL	EXAMPLES OF MATERIAL Hole injection materials	PUBLICATIONS
		US20010015432
		US20100295032
Monomer for polymeric metal organometallic compounds		U.S. Pat. No. 7,250,226, U.S. Pat. No. 7,396,598
Pt(II) organometallic complexes, including polydentated ligands		Appl. Phys. Lett. 86, 153505 (2005)
		Appl. Phys. Lett. 86, 153505 (2005)

TABLE 1-continued

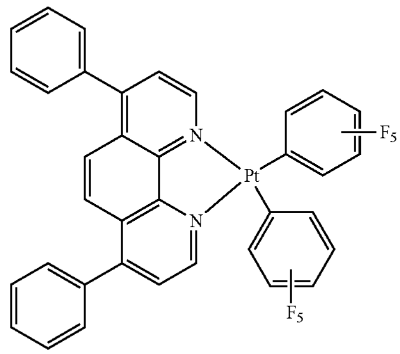
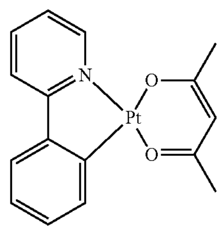
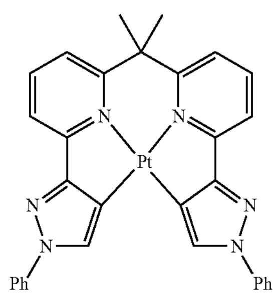
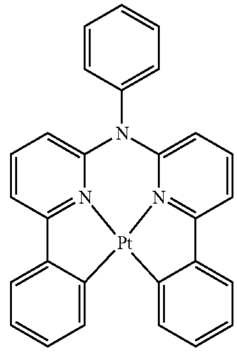
MATERIAL	EXAMPLES OF MATERIAL Hole injection materials	PUBLICATIONS
		Chem. Lett. 34, 592 (2005)
		WO2002015645
		US20060263635
		US20060182992 US20070103060

TABLE 1-continued

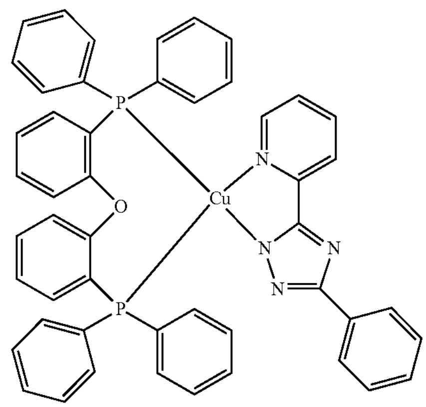
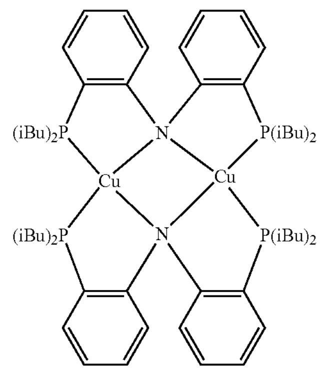
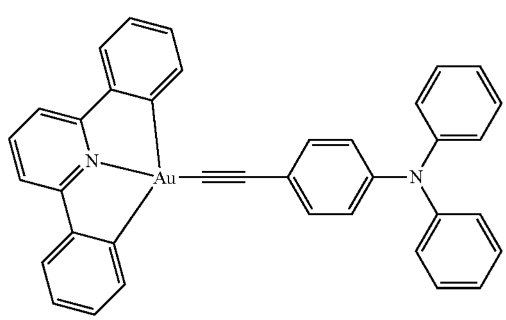
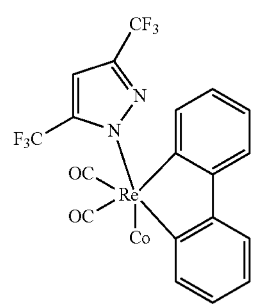
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
	Hole injection materials	
Cu complexes		WO2009000673
		US20070111026
Gold complexes		Chem. Commun. 2906 (2005)
Rhenium(III) complexes		Inorg. Chem. 42, 1248 (2003)

TABLE 1-continued

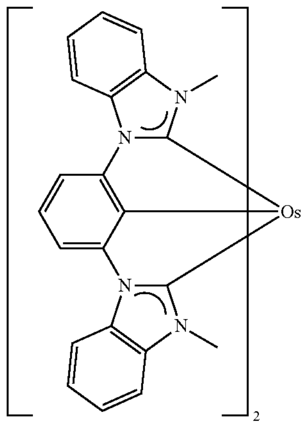
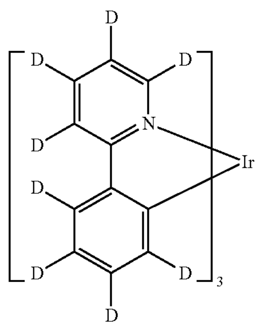
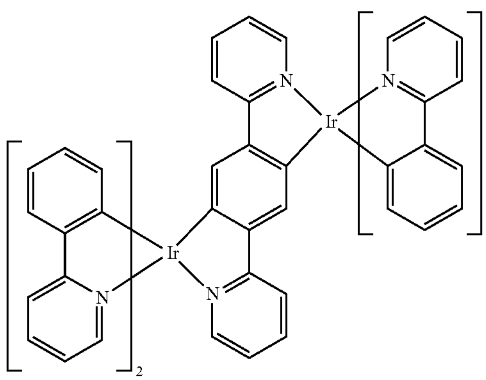
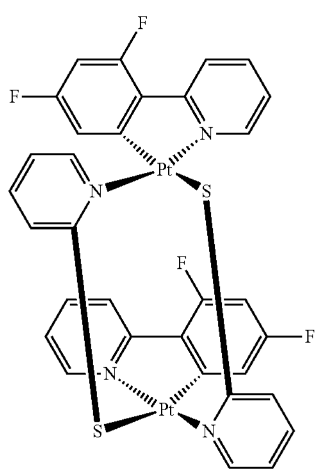
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
	Hole injection materials	
Osmium(II) complexes		U.S. Pat. No. 7,279,704
Deuterated organometallic complexes		US20030138657
Organometallic complexes with two or more metal centers		US20030152802
		U.S. Pat. No. 7,090,928

TABLE 1-continued

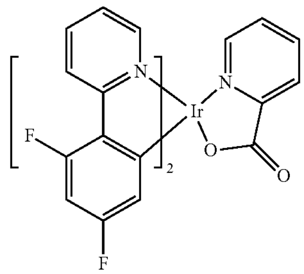
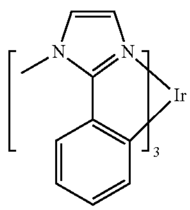
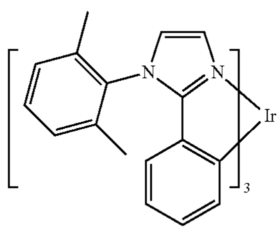
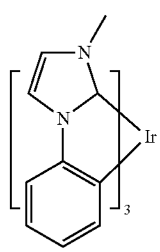
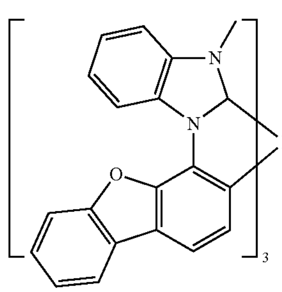
MATERIAL	EXAMPLES OF MATERIAL Hole injection materials	PUBLICATIONS
Blue dopants		
Iridium(III) organometallic Complexes		WO2002002714
		WO2006009024
		US20060251923 US20110057559 US20110204333
		U.S. Pat. No. 7,393,599, WO2006056418, US20050260441, WO2005019373
		U.S. Pat. No. 7,534,505

TABLE 1-continued

MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
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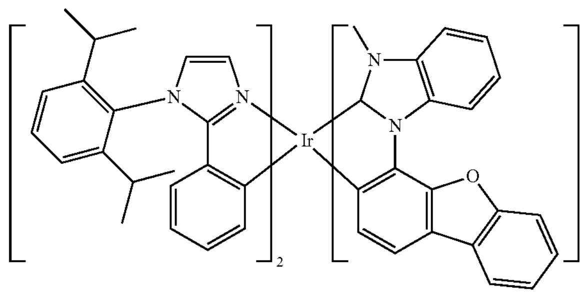
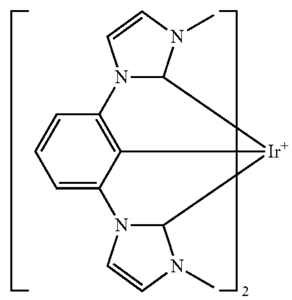
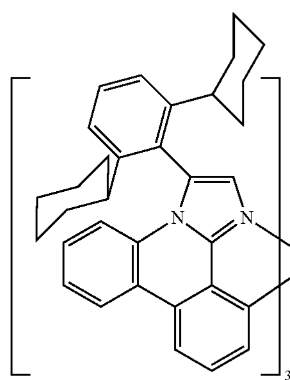
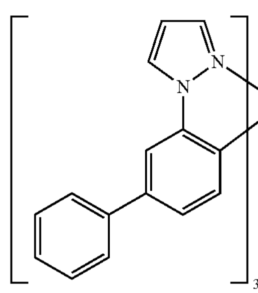
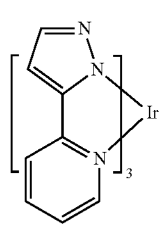
		WO2011051404
		U.S. Pat. No. 7,445,855
		US20070190359, US20080297033 US20100148663
		U.S. Pat. No. 7,338,722
		US20020134984

TABLE 1-continued

MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
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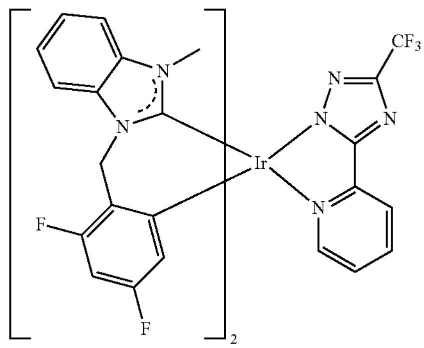
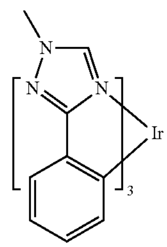
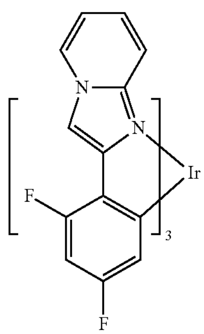
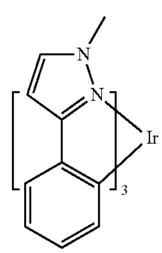
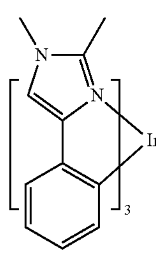
		Angew. Chem. Int. Ed. 47, 4542 (2008)
		Chem. Mater. 18, 5119 (2006)
		Inorg. Chem. 46, 4308 (2007)
		WO2005123873
		WO2005123873

TABLE 1-continued

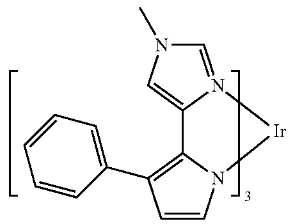
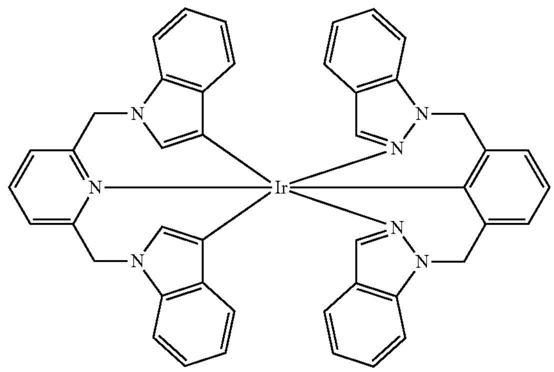
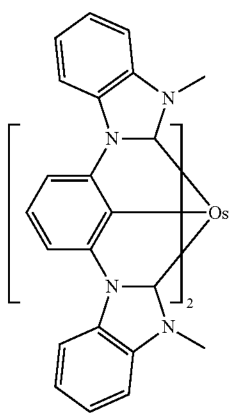
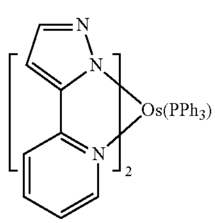
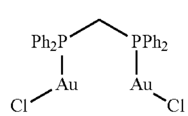
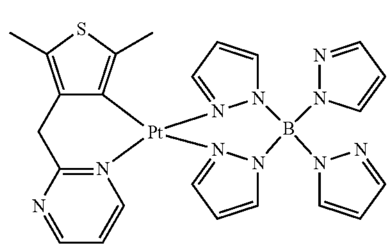
MATERIAL	EXAMPLES OF MATERIAL Hole injection materials	PUBLICATIONS
		WO2007004380
		WO2006082742
Osmium(II) complexes		U.S. Pat. No. 7,279,704
		Organometallics 23, 3745 (2004)
Gold complexes		Appl. Phys. Lett. 74, 1361 (1999)
Platinum(II) complexes		WO2006098120, WO2006103874

TABLE 1-continued

MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
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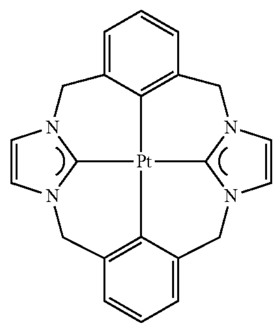
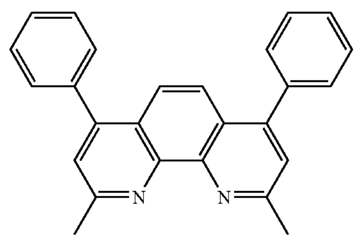
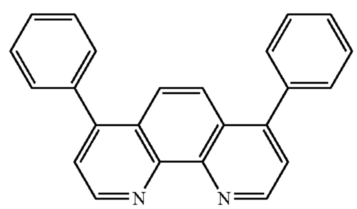
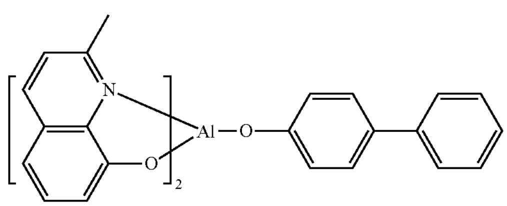
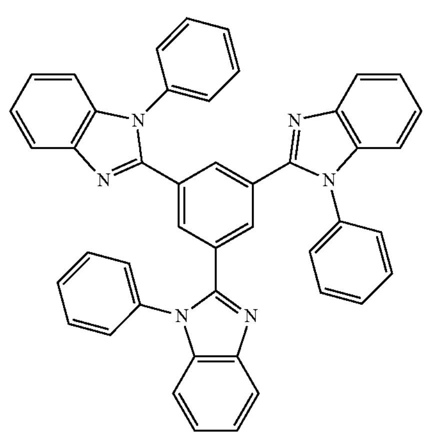
Pt tetradentate complexes with at least one metal-carbene bond		U.S. Pat. No. 7,655,323
Exciton/hole blocking layer materials		
Bathocuprine compounds (e.g., BCP, BPhen)		Appl. Phys. Lett. 75, 4 (1999)
		Appl. Phys. Lett. 79, 449 (2001)
Metal 8-hydroxyquinolates (e.g., BAlq)		Appl. Phys. Lett. 81, 162 (2002)
5-member ring electron deficient heterocycles such as triazole, oxadiazole, imidazole, benzoimidazole		Appl. Phys. Lett. 81, 162 (2002)

TABLE 1-continued

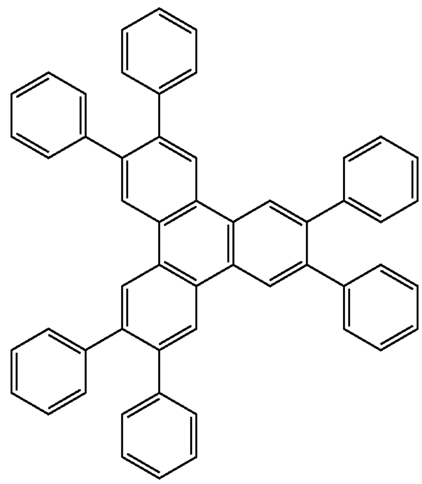
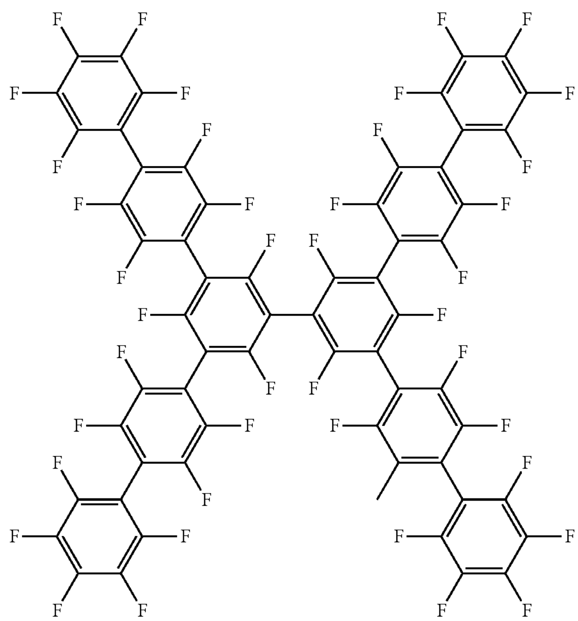
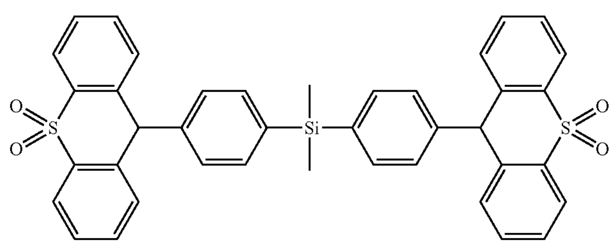
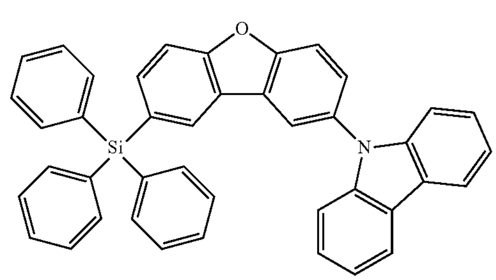
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
	Hole injection materials	
Triphenylene compounds		US20050025993
Fluorinated aromatic compounds		Appl. Phys. Lett. 79, 156 (2001)
Phenothiazine-S-oxide		WO2008132085
Silylated five-membered nitrogen, oxygen, sulfur or phosphorus dibenzoheterocycles		WO2010079051

TABLE 1-continued

MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
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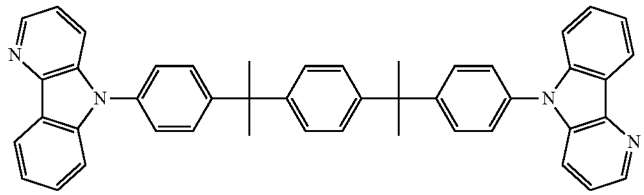
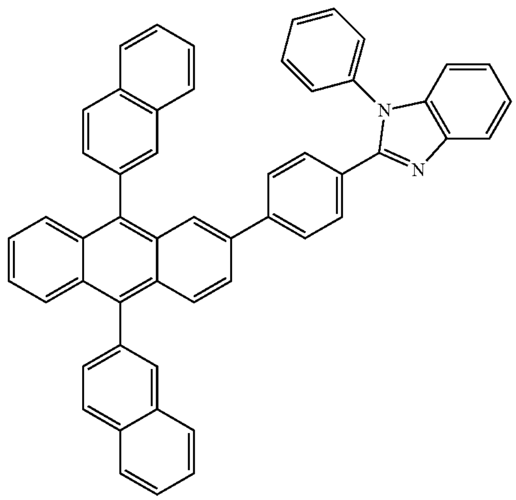
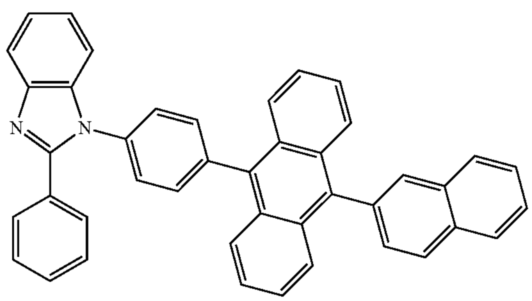
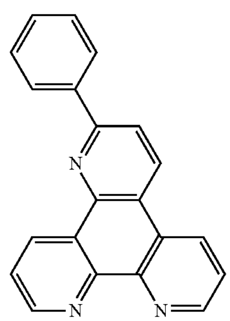
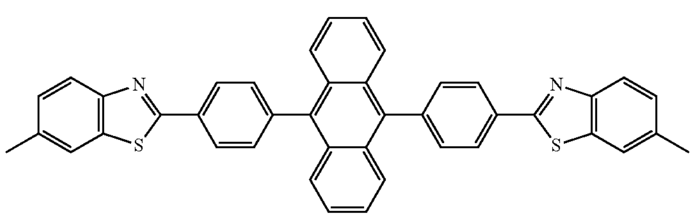
Aza-carbazoles		US20060121308
Electron transporting materials		
Anthracene-benzoimidazole compounds		WO2003060956
		US20090179554
Aza triphenylene derivatives		US20090115316
Anthracene-benzothiazole compounds		Appl. Phys. Lett. 89, 063504 (2006)

TABLE 1-continued

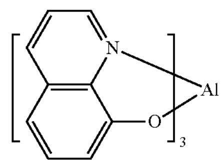
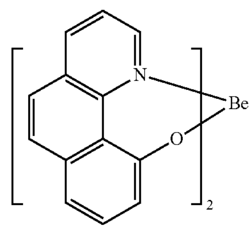
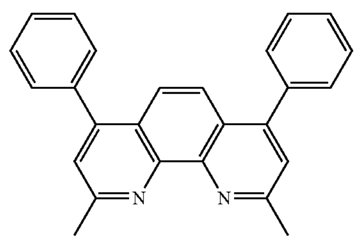
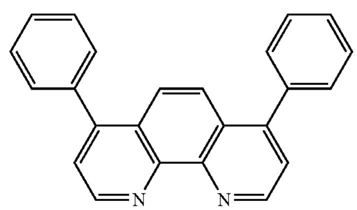
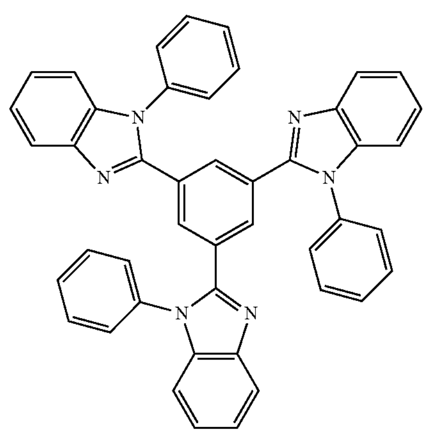
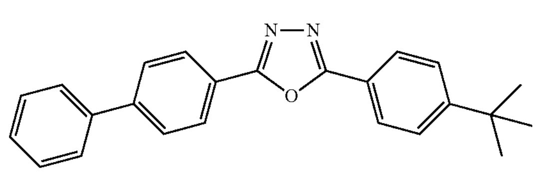
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
	Hole injection materials	
Metal 8-hydroxyquinolates (e.g., Alq_3, Zrq_4)		Appl. Phys. Lett. 51, 913 (1987) U.S. Pat. No. 7,230,107
Metal hydroxybenoquinolates		Chem. Lett. 5, 905 (1993)
Bathocuprine compounds such as BCP, BPhen, etc		Appl. Phys. Lett. 91, 263503 (2007)
		Appl. Phys. Lett. 79, 449 (2001)
5-member ring electron deficient heterocycles (e.g., triazole, oxadiazole, imidazole, benzoimidazole)		Appl. Phys. Lett. 74, 865 (1999)
		Appl. Phys. Lett. 55, 1489 (1989)

TABLE 1-continued

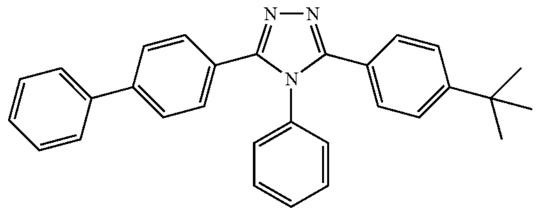
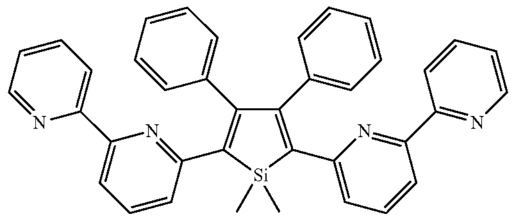
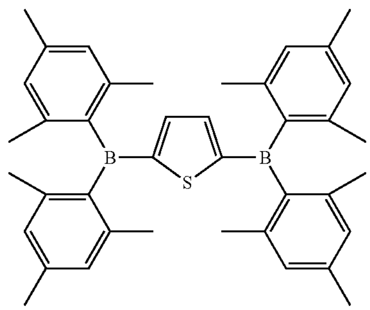
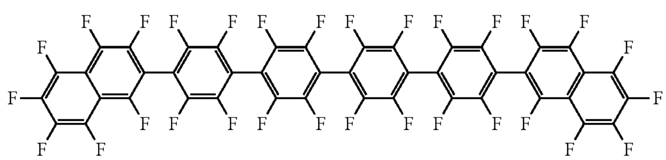
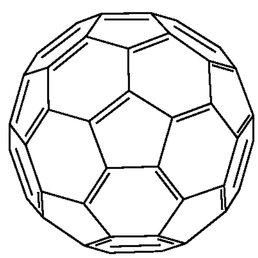
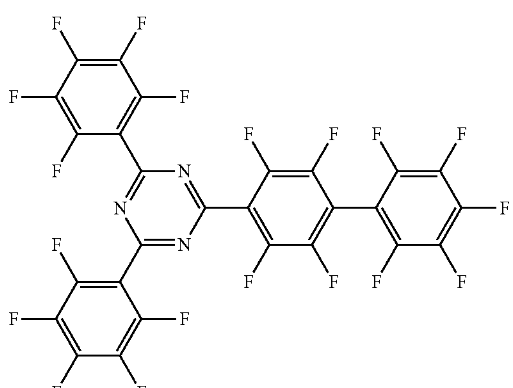
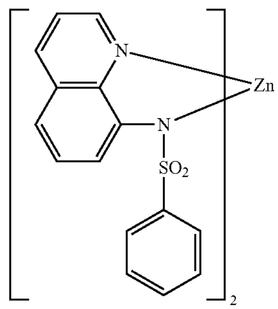
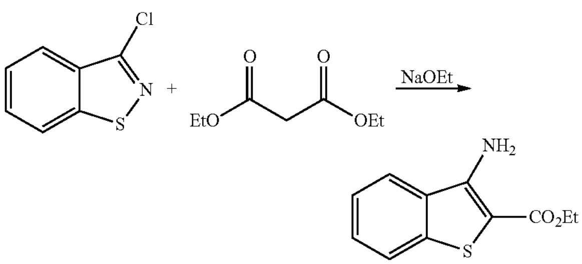
MATERIAL	EXAMPLES OF MATERIAL Hole injection materials	PUBLICATIONS
		Jpn. J. Apply. Phys. 32, L917 (1993)
Silole compounds		Org. Electron. 4, 113 (2003)
Arylborane compounds		J. Am. Chem. Soc. 120, 9714 (1998)
Fluorinated aromatic compounds		J. Am. Chem. Soc. 122, 1832 (2000)
Fullerene (e.g., C60)		US20090101870
Triazine complexes		US20040036077

TABLE 1-continued

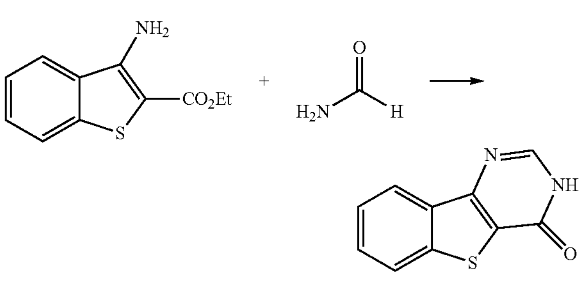
MATERIAL	EXAMPLES OF MATERIAL	PUBLICATIONS
	Hole injection materials	
Zn (N^N) complexes		U.S. Pat. No. 6,528,187

Compound Examples

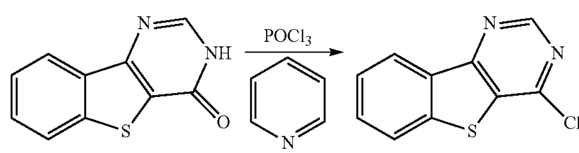
Synthesis of Compound S-10-144-H



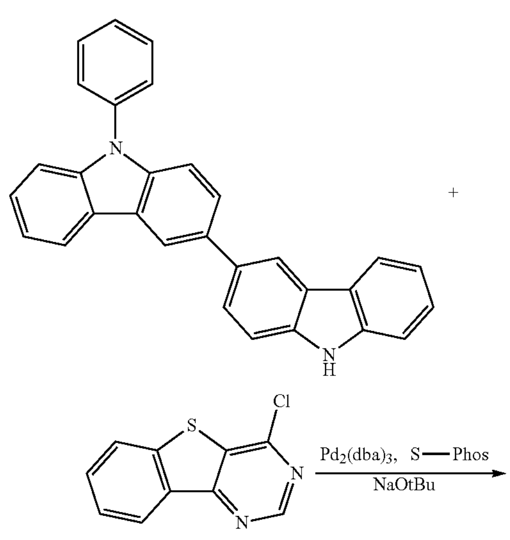
Synthesis of ethyl 3-aminobenzo[b]thiophene-2-carboxylate: A dry 2-neck 500 mL round-bottom flask (RBF) was charged with sodium ethanolate (46.2 mL, 124 mmol), diluted with 151 mL absolute EtOH, cooled in an ice bath and treated dropwise with diethyl malonate (17.98 mL, 118 mmol) under an atmosphere of nitrogen. After stirring for 20 minutes, the ice bath was removed and 3-chlorobenzo[d]isothiazole (20.0 g, 118 mmol) was added in one portion and stirred for 24 hours. The reaction solution was quenched with water, extracted with ether and treated with excess 4 M HCl/dioxane. A pinkish-white precipitate was filtered off, suspended in water, basified with Na_2CO_3, extracted with ether, washed with water and brine, dried over sodium sulfate, filtered and concentrated to yellow solids (~20 g) which were recrystallized from ethanol/water and dried in a vacuum oven at 60° C. for 3 hrs to give ethyl 3-aminobenzo[b]thiophene-2-carboxylate (19.9 g, 76% yield).



Synthesis of benzo[4,5]thieno[3,2-d]pyrimidin-4(3H)-one: A 100 mL RBF was charged with ethyl 3-aminobenzo[b]thiophene-2-carboxylate (17.7 g, 80 mmol), treated with formamide (60.6 mL, 1520 mmol) and heated to 190° C. for 2 hrs. Precipitate formed upon cooling. The solid precipitate was collected by filtration and washed with ether, then recrystallized from ethanol/tetrahydrofuran. Benzo[4,5]thieno[3,2-d]pyrimidin-4(3H)-one (9.9 g, 61% yield) was obtained.



Synthesis of 4-chlorobenzo[4,5]thieno[3,2-d]pyrimidine: Benzo[4,5]thieno[3,2-d]pyrimidin-4(3H)-one (10.78 g, 26.7 mmol) was treated with pyridine (2.68 mL, 33.3 mmol) and phosphoryl trichloride (53.4 mL, 573 mmol), then heated to reflux at 110° C. for 1 hr. Excess POC_3 was removed and cautiously quenched with ice water in an ice bath. The pH was adjusted to ~5 with ammonium hydroxide. Solid was collected by filtration washed with water. The solid was dried to give 4-chlorobenzo[4,5]thieno[3,2-d]pyrimidine (10 g, 85% yield).



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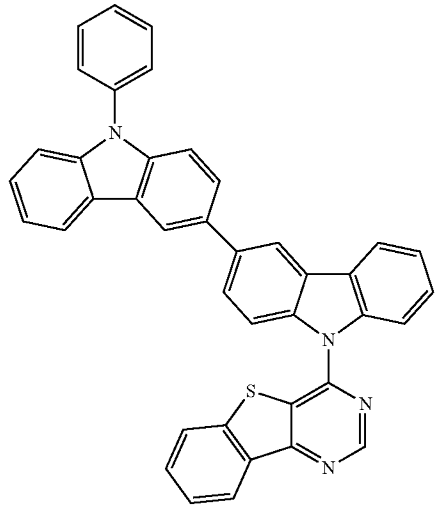
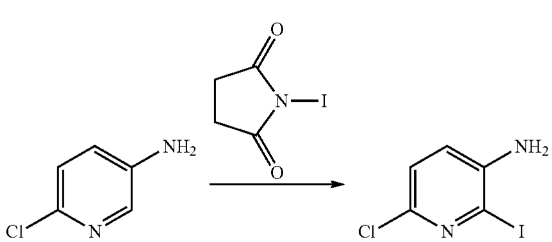
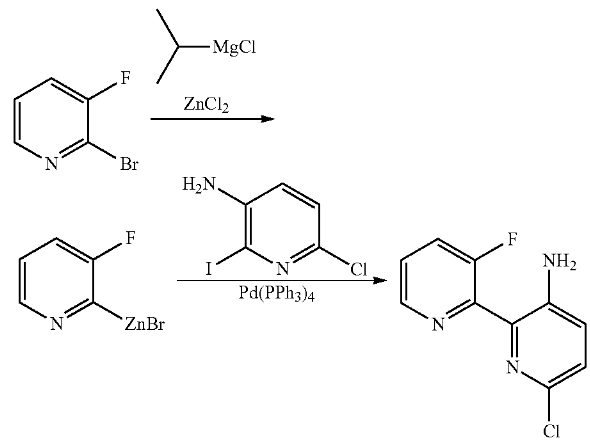


Synthesis of 4-(9'-phenyl-9H,9'H-[3,3'-bicarbazol]-9-yl)benzo[4,5]thieno[3,2-d]pyrimidine: 9-phenyl-9H,9'H-3,3'-bicarbazole (3.05 g, 7.47 mmol), 4-chlorobenzo[4,5]thieno[3,2-d]pyrimidine (1.812 g, 8.21 mmol), Pd_2dba_3 (0.342 g, 0.373 mmol), dicyclohexyl(2',6'-dimethoxy-[1,1'-biphenyl]-2-yl)phosphine (S-Phos) (0.307 g, 0.747 mmol), and sodium 2-methylpropan-2-olate (1.794 g, 18.67 mmol) were charged to a 250 mL RBF, diluted in m-Xylene (Volume: 74.7 mL), degassed with nitrogen and heated to reflux at 150° C. overnight. The reaction was quenched with aqueous ammonium chloride and filtered through a plug of Celite® with dichloromethane (DCM). The crude was purified by column chromatography and then recrystallized from toluene/ethanol to give 4-(9'-phenyl-9H,9'H-[3,3'-bicarbazol]-9-yl)benzo[4,5]thieno[3,2-d]pyrimidine (1.95 g, 44% yield).

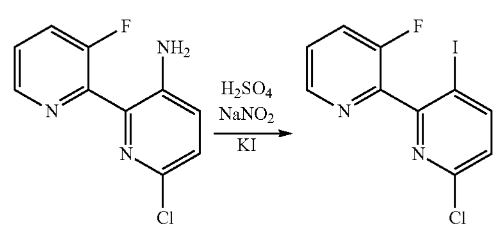
Synthesis of Compound S-17-144-H



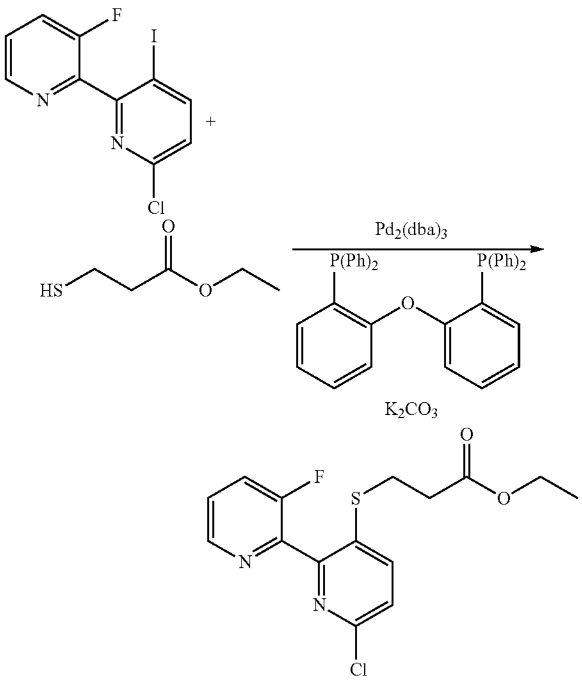
Synthesis of 6-chloro-2-iodopyridin-3-amine: 6-chloropyridin-3-amine (40.0 g, 311 mmol) was dissolved in dimethylformamide (DMF) (Volume: 534 mL) and treated with 1-iodopyrrolidine-2,5-dione (70.0 g, 311 mmol) in one portion. The reaction solution was stirred at room temperature under nitrogen overnight and quenched with water and extracted with EtOAc and Et_2O. Organic layer was washed twice with brine and dried over sodium sulfate. DMF was removed on kugelrohr at 100° C. to afford ~90 g red solids. The crude was purified via column chromatography to give 6-chloro-2-iodopyridin-3-amine (57 g, 72% yield).



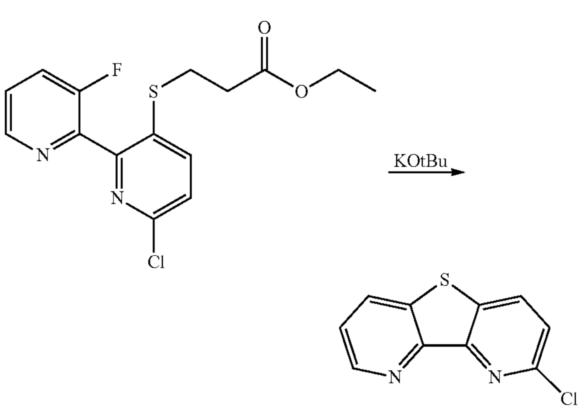
Synthesis of 6-chloro-3'-fluoro-[2,2'-bipyridin]-3-amine: A 3-neck 1000 mL RBF was dried under vacuum, then charged with isopropylmagnesium chloride (78 mL, 156 mmol) and cooled with a water bath. 2-bromo-3-fluoropyridine (14.37 mL, 142 mmol) was added dropwise making sure temperature did not exceed 30° C. The reaction was stirred at room temperature overnight, then treated dropwise with zinc (II) chloride (341 mL, 170 mmol) over 3 hrs and stirred at room temperature overnight. This suspension was then added dropwise via canula to a degassed, 65° C. solution of $Pd(PPh_3)_4$ (8.21 g, 7.10 mmol) and 6-chloro-2-iodopyridin-3-amine (39.8 g, 156 mmol) in tetrahydrofuran (THF) (Volume: 474 mL) and heated at reflux overnight. After cooled to room temperature, the reaction was quenched with sat. aq. $NaHCO_3$ and water. The precipitate was filtered out and washed with EtOAc. The filtrate was extracted with EtOAc. The crude product was purified by column chromatography in 40-50% EtOAc/hexanes with column conditioned in 20% TEA/hexanes to give 6-chloro-3'-fluoro-[2,2'-bipyridin]-3-amine (21.8 g, 69% yield).



Synthesis of 6-chloro-3'-fluoro-3-iodo-2,2'-bipyridine: A 500 mL 3 neck RBF equipped with mechanical stirrer, reflux condenser, and addition funnel was charged with 6-chloro-3'-fluoro-[2,2'-bipyridin]-3-amine (6.63 g, 29.6 mmol). It was treated with 2M sulfuric acid (111 mL, 222 mmol) creating a yellow/orange solution. The reaction was cooled to −5° C. and treated dropwise with a solution of sodium nitrile (2.66 g, 38.5 mmol) in 49 mL water at −5° C. The yellow/orange suspension was stirred at 0° C. for 30 minutes, then treated dropwise with a solution of potassium iodide (14.76 g, 89 mmol) in 63 mL of water. The reaction was stirred at room temperature for 30 minutes, then heated to 80° C. for 1 hour. After cooling, the reaction was extracted with EtOAc, washed with water, 2M Na_2CO_3, $NaHSO_3$, and brine, dried over sodium sulfate, filtered, and concentrated. The crude product was purified by column chromatography using 20% EtOAc/hexanes to give 6-chloro-3'-fluoro-3-iodo-2,2'-bipyridine (16 g, 81% yield).

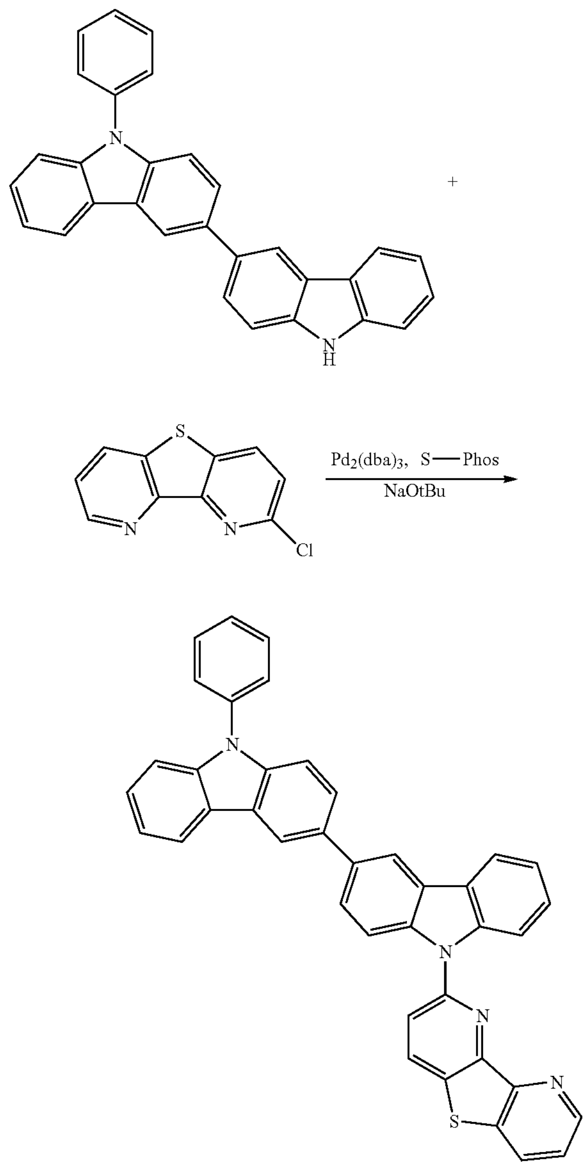


Synthesis of ethyl 3-((6-chloro-3'-fluoro-[2,2'-bipyridin]-3-yl)thio)propanoate:_6-chloro-3'-fluoro-3-iodo-2,2'-bipyridine (21.4 g, 64.0 mmol), Potassium Carbonate (22.10 g, 160 mmol), (oxybis(2,1-phenylene))bis(diphenylphosphine) (3.45 g, 6.40 mmol), $Pd_2(dba)_3$ (2.93 g, 3.20 mmol) were charged to a dry 500 mL RBF, taken up in Toluene (Volume: 256 mL) and degassed with nitrogen. Ethyl 3-mercaptopropanoate (8.92 mL, 70.4 mmol) was added and the reaction solution was heated to reflux for 7 hours. The reaction was quenched with NH_4Cl and extracted with EtOAc. The crude was purified by column chromatography using EtOAc and hexanes to give ethyl 3-((6-chloro-3'-fluoro-[2,2'-bipyridin]-3-yl)thio)propanoate (21.5 g, ~100% yield) with some impurities.



Synthesis of 2-chlorothieno[3,2-b:4,5-b']dipyridine: A 500 mL RBF was charged with ethyl 3-((6-chloro-3'-fluoro-[2,2'-bipyridin]-3-yl)thio)propanoate (16.55 g, 48.6 mmol), THF (Volume: 194 mL) and degassed with nitrogen for 10 minutes, then treated with potassium 2-methylpropan-2-olate (8.17 g, 72.8 mmol) and heated to reflux at 75° C. for 24 hours. The reaction was quenched with aqueous ammonium chloride, extracted 2× with EtOAc. The crude product was purified by column chromatography to give 2-chlorothieno[3,2-b:4,5-b'] dipyridine (7 g, 68% yield).

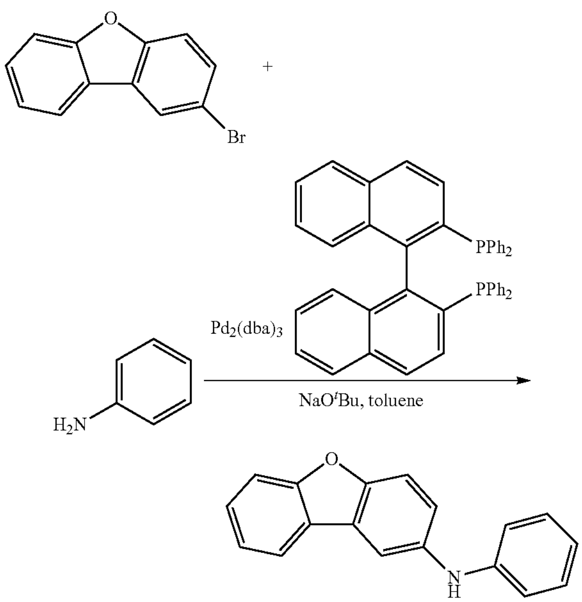
Synthesis of Compound S-17-144-H



9-phenyl-9H,9'H-3,3'-bicarbazole (3.0 g, 7.34 mmol), 2-chlorothieno[3,2-b:4,5-b']dipyridine (2.026 g, 9.18 mmol), Pd_2dba_3 (0.336 g, 0.367 mmol), dicyclohexyl(2',6'-dimethoxy-[1,1'-biphenyl]-2-yl)phosphine (S-Phos) (0.301 g, 0.734 mmol), and sodium 2-methylpropan-2-olate (1.764 g, 18.36 mmol) were charged to a dry 250 mL RBF, treated with m-Xylene (Volume: 73.4 mL) and degassed with nitrogen then heated to reflux at 150° C. overnight. The reaction solution was cooled to room temperature, quenched with aq.

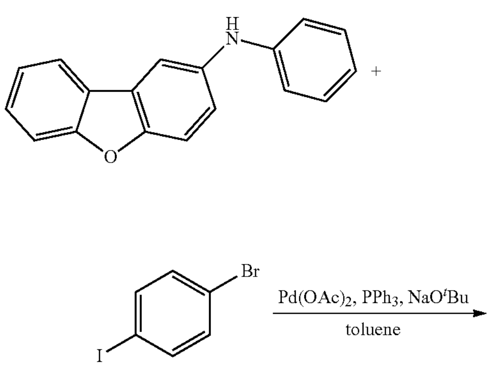
NH_4Cl and filtered through small plug of Celite® with DCM. The crude product was purified by column chromatography to give 1.86 g pure product.

Synthesis of N-phenyldibenzo[b,d]furan-2-amine



4-bromodibenzo[b,d]furan (3.0 g, 12.1 mmol) and aniline (1.69 g, 18.1 mmol) were mixed in 100 mL of toluene. The solution was bubbled with nitrogen for 15 min. $Pd_2(dba)_3$ (0.05 g, 0.05 mmol), 2,2'-bis(diphenylphosphino)-1,1'-binaphthyl (0.15 g, 0.24 mmol) and sodium t-butoxide (1.7 g, 17.4 mmol) were added. The mixture was refluxed overnight under nitrogen. After cooling, the reaction mixture was filtered through celite/silica pad and the filtrate was concentrated under vacuum. The residue was then purified by column chromatography using DCM:hexane (1:1, v/v) as the eluent. 2.0 g (65%) of a white solid was obtained as the product.

Synthesis of N-(4-bromophenyl)-N-phenyldibenzo[b,d]furan-2-amine



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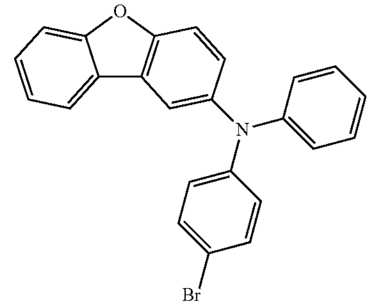
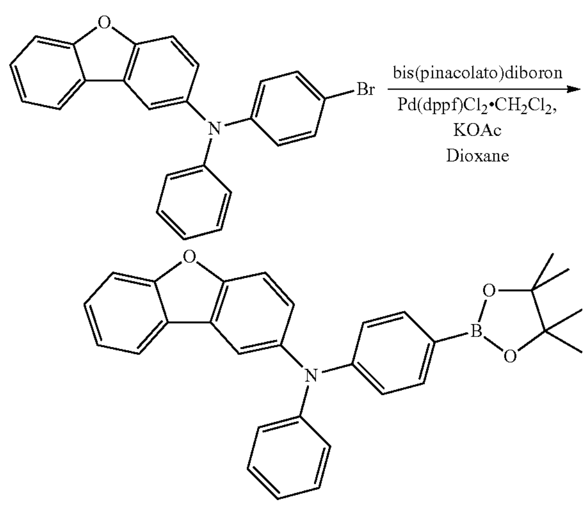


N-phenyldibenzo[b,d]furan-2-amine (5.0 g, 19.3 mmol), and 1-bromo-4-iodobenzene (10.9 g, 38.6 mmol) were mixed in 100 mL of toluene. The solution was bubbled with nitrogen for 15 min. $Pd(OAc)_2$ (0.22 g, 1.0 mmol), triphenylphosphine (0.51 g, 1.9 mmol) and sodium t-butoxide (2.2 g, 23.1 mmol) were added. The mixture was refluxed overnight under nitrogen.

After cooling, the reaction mixture was filtered through celite/silica pad and the filtrate was concentrated under vacuum. The residue was then purified by column chromatography using DCM:hexane (1:1, v/v) as the eluent. 5.6 g (71%) of a yellow solid was obtained as the product.

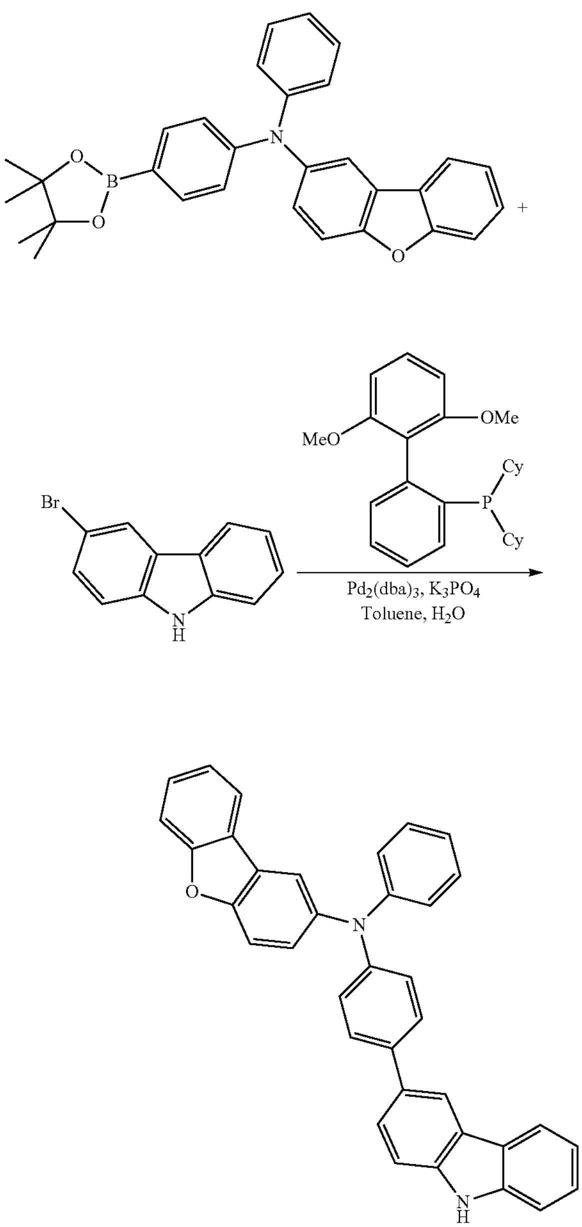
Synthesis of N-phenyl-N-(4-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)phenyl)dibenzo[b,d]furan-2-amine



N-(4-bromophenyl)-N-phenyldibenzo[b,d]furan-2-amine (5.3 g, 12.8 mmol), bis(pinacolato)diboron (11.4 g, 44.8 mmol) and KOAc (3.77 g, 38.4 mmol) were mixed in 130 mL of dry 1,4-dioxane. The solution was bubbled with nitrogen for 15 minutes, then $Pd(dppf)Cl_2.CH_2Cl_2$ (0.28 g, 0.4 mmol) was added. The mixture was refluxed overnight under nitrogen. After cooling, the reaction mixture was filtered through celite/silica pad and the solvent was then evaporated. The residue was then purified by column chromatography using

DCM:hexane (1:3, v/v) as the eluent. 5.21 g (88%) of a white solid was obtained as the product.

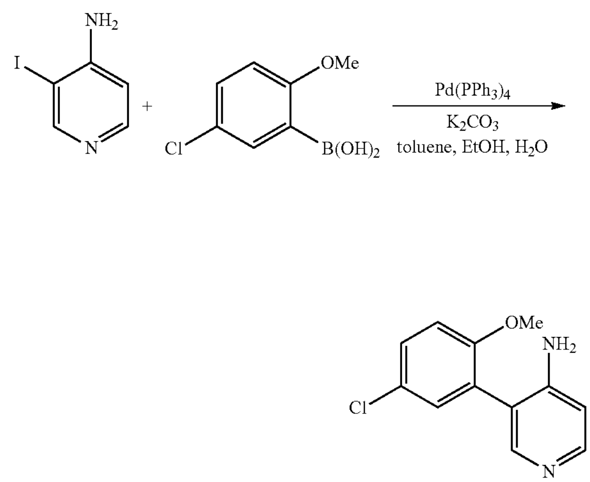
Synthesis of N-(4-(9H-carbazol-3-yl)phenyl)-N-phenyldibenzo[b,d]furan-2-amine



N-phenyl-N-(4-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)phenyl)dibenzo[b,d]furan-2-amine (3.25 g, 7.0 mol), and 3-bromo-9H-carbazole (1.73 g, 7.0 mmol) were mixed in 45 mL of toluene and 15 ml of ethanol. To the solution was bubbled with nitrogen for 15 min. $Pd_2(dba)_3$ (0.16 g, 0.18 mmol), 2-dicyclohexylphosphino-2',6'-dimethoxybiphenyl (0.29 g, 7.0 mmol) and K_3PO_4 (4.49 g, 21.1 mmol) were added. The mixture was refluxed overnight under nitrogen. After cooling, aqueous layer was removed from the reaction mixture and dry over magnesium sulfate, and was filtered through filter paper and the filtrate was then evaporated. The

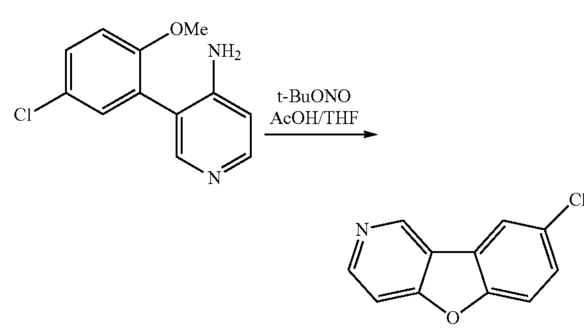
residue was then purified by column chromatography using THF:hexane (1:3, v/v) as eluent 3.0 g (85%) of a white solid was obtained as the product.

Synthesis of 3-(5-chloro-2-methoxyphenyl)pyridin-4-amine



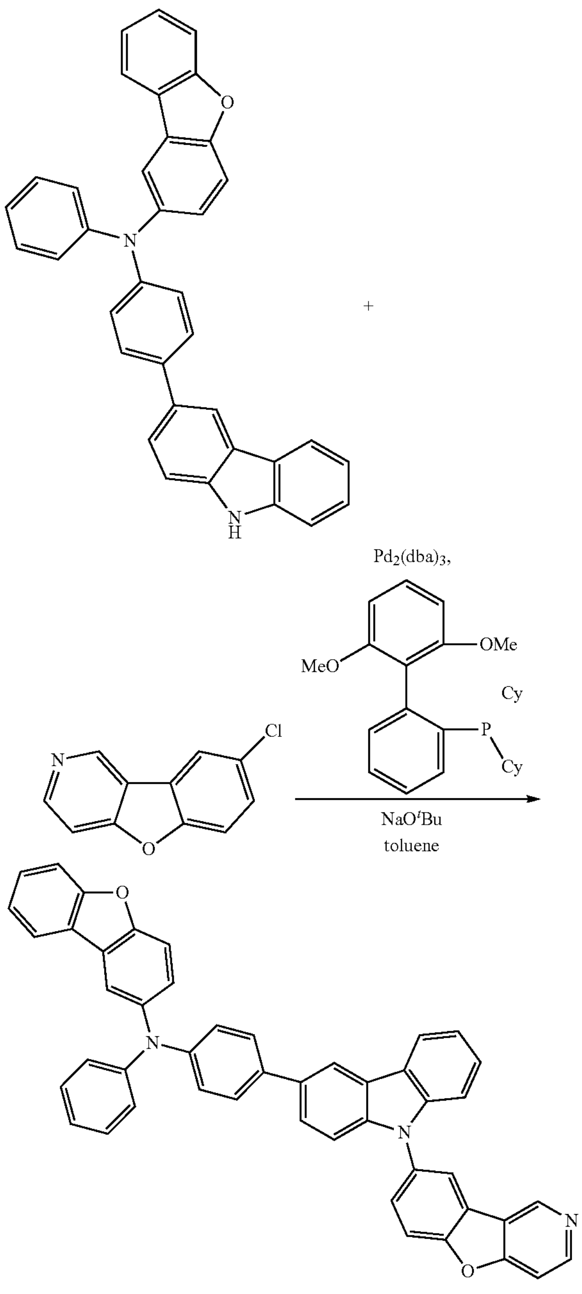
3-iodopyridin-4-amine (2.2 g, 10 mmol), (5-chloro-2-methoxyphenyl)boronic acid (1.86 g, 10 mmol) and, and K_2CO_3 (4.2 g, 30 mmol) were mixed in 50 mL of toluene, 5 mL of deionized water and 5 mL of ethanol. To the solution was bubbled with nitrogen for 15 min. $Pd(PPh_3)_4$ (0.23 g, 0.2 mmol) was then added. The mixture was refluxed overnight under nitrogen. After cooling, the aqueous layer was removed and the organic layer was then concentrated. The residue was then purified by column chromatography using ethyl acetate as the eluent. 2.0 g (85%) of product was collected as the product.

Synthesis of 8-chlorobenzofuro[3,2-c]pyridine



3-(5-chloro-2-methoxyphenyl)pyridin-4-amine (2 g, 8.5 mmol) was dissolved in 25 mL of acetic acid and 10 mL of THF at −10° C. To the solution t-butyl nitrile (2 ml, 17 mmol) was dropwisely added. The mixture was warmed to room temperature overnight. Water was added to the reaction mixture and was extracted by dichloromethane, the organic layer was then dried by $MgSO_4$ and concentrated. The residue was then purified by column chromatography using THF:hexane (1:3, v/v) as the eluent. 0.8 g (46%) of product was collected as the product.

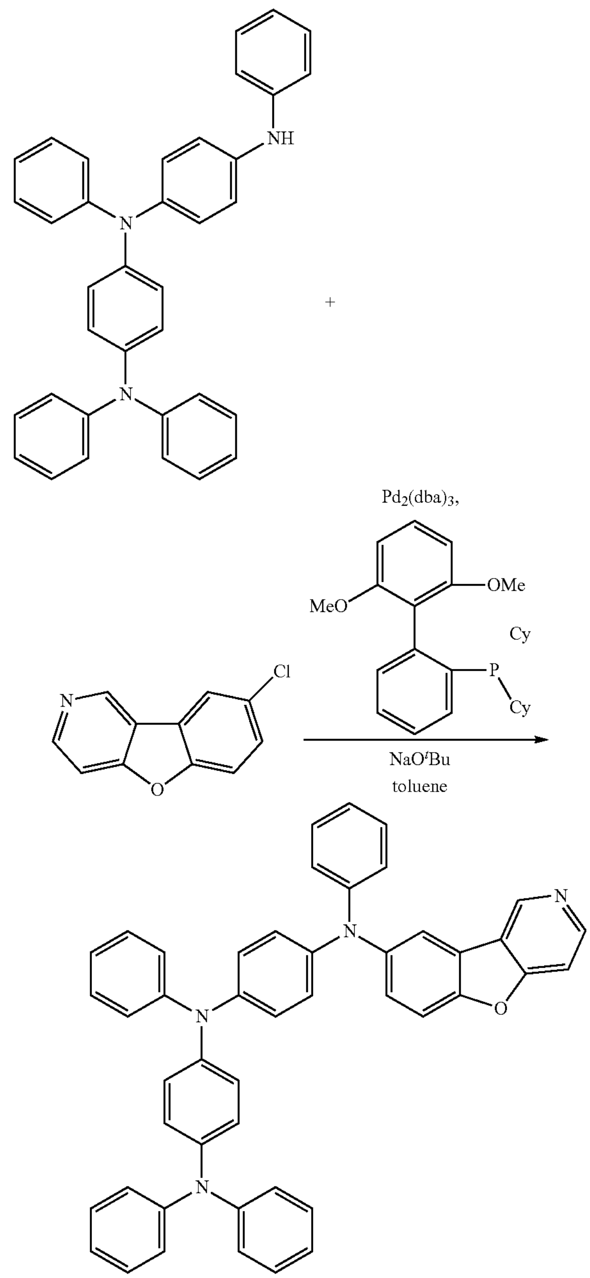
Synthesis of Compound O-20-10-H



N-(4-(9H-carbazol-3-yl)phenyl)-N-phenyldibenzo[b,d]furan-2-amine (0.76 g, 1.5 mmol) and 8-chlorobenzofuro[3,2-c]pyridine (0.3 g, 1.48 mmol) were mixed in 70 mL of dry xylene. To the solution was bubbled with nitrogen for 15 min. $Pd_2(dba)_3$ (0.16 g, 0.17 mmol), 2-dicyclohexylphosphino-2',6'-dimethoxybiphenyl (0.24 g, 0.58 mmol) and ^{t}BuONa (0.23 g, 2.4 mmol) were then added. The mixture was refluxed overnight under nitrogen. After cooling, the reaction mixture was filtered through celite/silica pad and the solvent was then

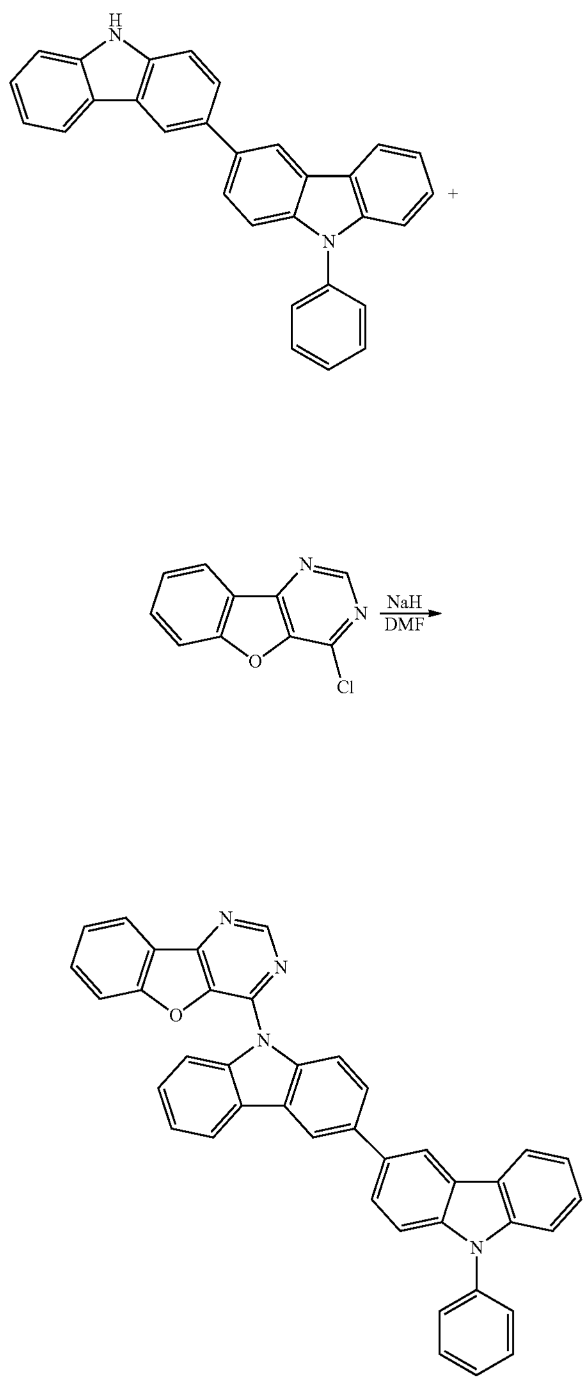
concentrated. The residue was then purified by column chromatography using THF:hexane (1:4, v/v) as the eluent. 0.3 g (30%) of product was collected.

Synthesis of Compound O-20-7-H



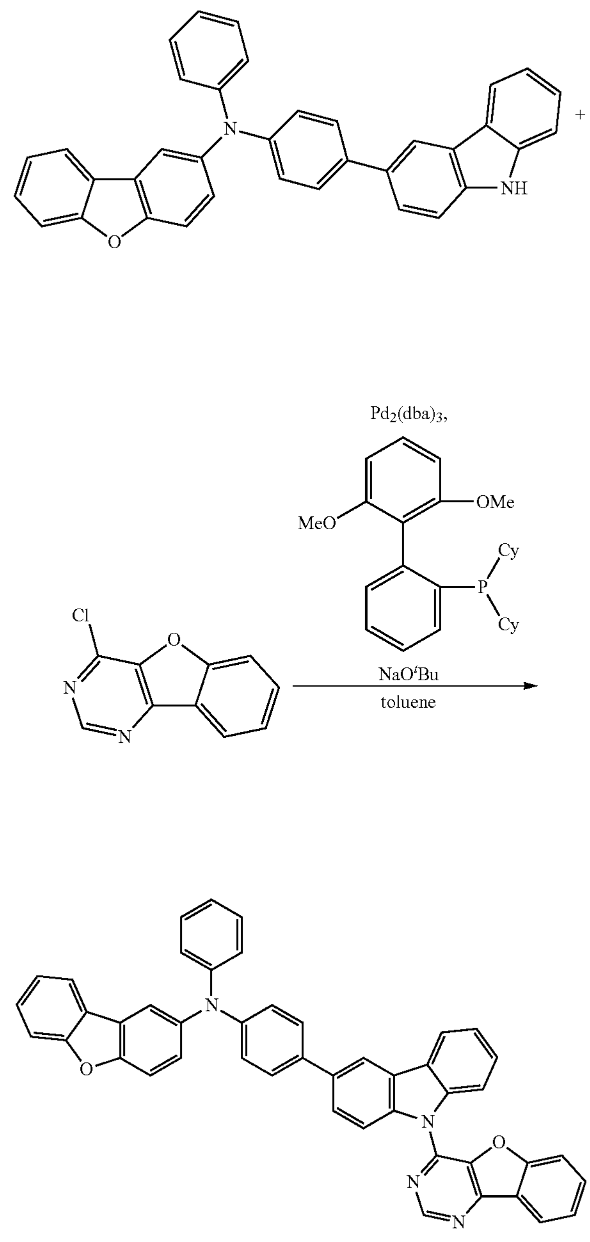
N^1,N^1,N^4-triphenyl-N^4-(4-(phenylamino)phenyl)benzene-1,4-diamine (0.76 g, 1.5 mmol) and 8-chlorobenzofuro[3,2-c]pyridine (0.3 g, 1.48 mmol) were mixed in 70 mL of dry xylene. To the solution was bubbled with nitrogen for 15 min. $Pd_2(dba)_3$ (0.16 g, 0.17 mmol), 2-dicyclohexylphosphino-2',6'-dimethoxybiphenyl (0.24 g, 0.58 mmol) and ^{t}BuONa (0.23 g, 2.4 mmol) were then added. The mixture was refluxed overnight under nitrogen. After cooling, the reaction mixture was filtered through celite/silica pad and the solvent was then concentrated. The residue was then purified by column chromatography using THF:hexane (1:4, v/v) as the eluent. 0.55 g (55%) of product was collected as the product.

Synthesis of Compound O-10-144-H



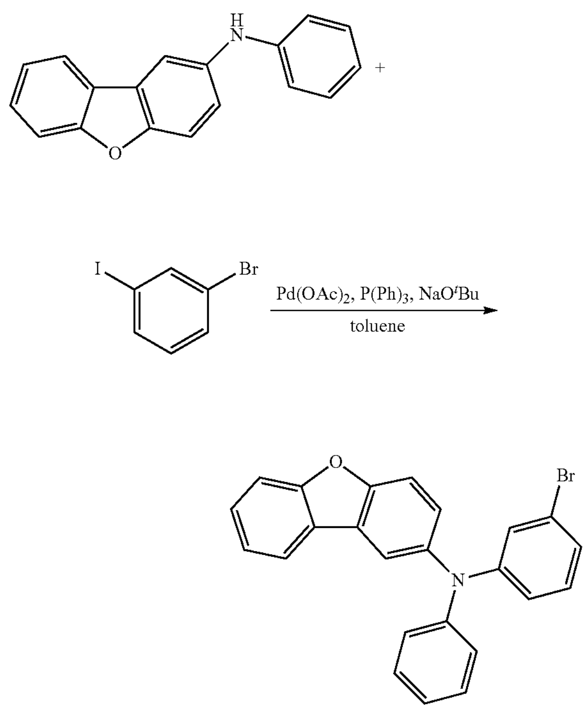
9-phenyl-9H,9'H-3,3'-bicarbazole (2.7 g, 6.6 mmol) and sodium hydride (0.4 g, 10.4 mmol) were mixed in 30 mL of dry DMF. To the solution was stirred for 1 hour. 4-chlorobenzofuro[3,2-d]pyrimidine (1.6 g, 7.8 mmol) was added. The mixture was stirred overnight under nitrogen. The reaction mixture was poured into water and the precipitate was filtered. The residue was then purified by column chromatography using THF:hexane (1:4, v/v) as the eluent. 3.0 g (78%) of product was collected as the product.

Synthesis of Compound O-10-10-H



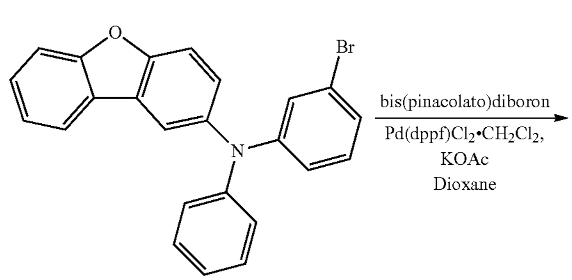
N-(4-(9H-carbazol-3-yl)phenyl)-N-phenyldibenzo[b,d]furan-2-amine (0.90 g, 1.8 mmol), and 4-chlorobenzofuro[3,2-d]pyrimidine (0.37 g, 1.8 mmol) were mixed in 10 mL of dry toluene. The solution was bubbled with nitrogen for 15 min. $Pd_2(dba)_3$ (0.082 g, 0.09 mmol), 2-dicyclohexylphosphino-2',6'-dimethoxybiphenyl (0.074 g, 0.18 mmol) and sodium t-butoxide (3.5 g, 3.6 mmol) were then added. The mixture was refluxed overnight under nitrogen. After cooling, the reaction mixture was filtered through celite/silica pad and the filtrate was concentrated under vacuum. The residue was then purified by column chromatography using gradient from hexane to THF:hexane (1:3, v/v) as the eluent. 0.40 g (33%) of a yellow solid was obtained as the product.

Synthesis of N-(3-bromophenyl)-N-phenyldibenzo[b,d]furan-2-amine



N-phenyldibenzo[b,d]furan-2-amine (5.0 g, 19.3 mmol), and 1-bromo-3-iodobenzene (10.9 g, 38.6 mmol) were mixed in 100 mL of toluene. The solution was bubbled with nitrogen for 15 min. $Pd(OAc)_2$ (0.22 g, 1.0 mmol), triphenylphosphine (0.51 g, 1.9 mmol) and sodium t-butoxide (2.2 g, 23.1 mmol) were then added. The mixture was refluxed overnight under nitrogen. After cooling, the reaction mixture was filtered through celite/silica pad and the filtrate was concentrated under vacuum. The residue was then purified by column chromatography using DCM:hexane (1:1, v/v) as the eluent. 5.6 g (71%) of a yellow solid was obtained as the product.

Synthesis of N-phenyl-N-(3-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)phenyl)dibenzo[b,d]furan-2-amine



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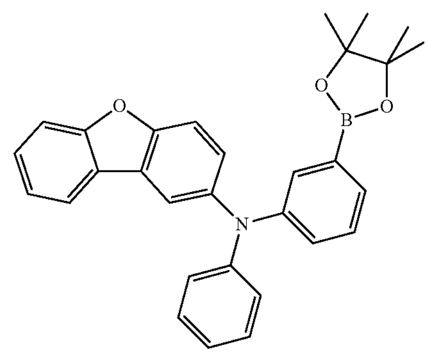
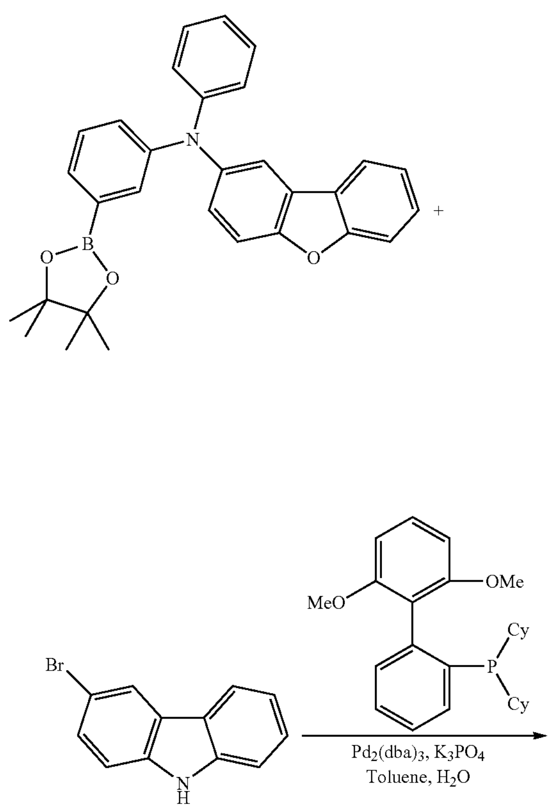


N-(3-bromophenyl)-N-phenyldibenzo[b,d]furan-2-amine (5.3 g, 12.8 mmol), bis(pinacolato)diboron (11.4 g, 44.8 mmol) and KOAc (3.77 g, 38.4 mmol) were mixed in 130 mL of dry 1,4-dioxane. The solution was bubbled with nitrogen for 15 minutes, then $Pd(dppf)Cl_2.CH_2Cl_2$ (0.28 g, 0.4 mmol) was added. The mixture was refluxed overnight under nitrogen. After cooling, the reaction mixture was filtered through celite/silica pad and the solvent was then concentrated. The residue was then purified by column chromatography using DCM:hexane (1:3, v/v) as the eluent. 5.21 g (88%) of a white solid was obtained as the product.

Synthesis of N-(3-(9H-carbazol-3-yl)phenyl)-N-phenyldibenzo[b,d]furan-2-amine



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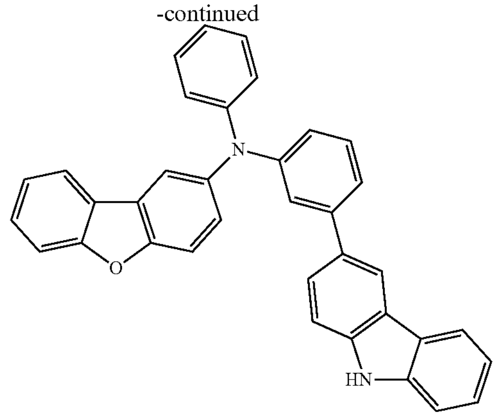
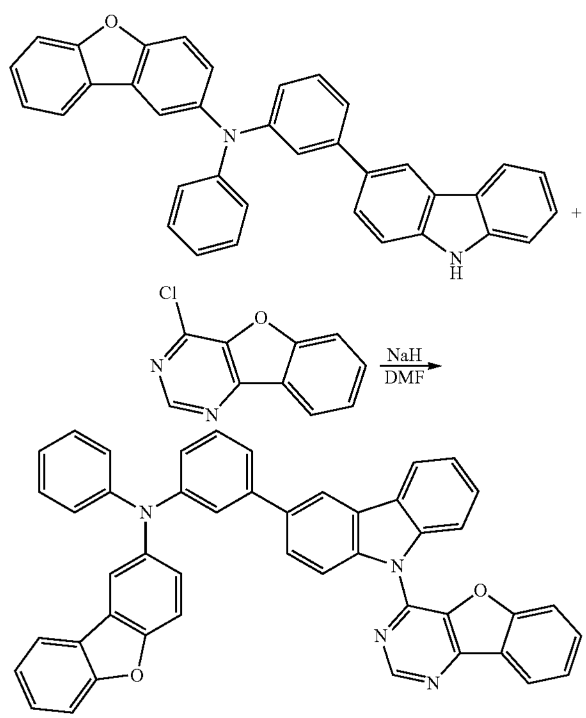


N-phenyl-N-(3-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)phenyl)dibenzo[b,d]furan-2-amine (3.25 g, 7.0 mol), and 3-bromo-9H-carbazole (1.73 g, 7.0 mmol) were mixed in 45 mL of toluene and 15 mL of ethanol. To the solution was bubbled with nitrogen for 15 min. $Pd_2(dba)_3$ (0.16 g, 0.18 mmol), 2-dicyclohexylphosphino-2',6'-dimethoxybiphenyl (0.29 g, 7.0 mmol) and K_3PO_4 (4.49 g, 21.1 mmol) were then added. The mixture was refluxed overnight under nitrogen.

After cooling, aqueous layer was removed from the reaction mixture and dry over magnesium sulfate, and was filtered through filter paper and the solvent was then concentrated. The residue was then purified by column chromatography using THF:hexane (1:3, v/v) as the eluent. 3.0 g (85%) of a whited solid was obtained as the product.

Synthesis of Compound O-10-31-H



N-(3-(9H-carbazol-3-yl)phenyl)-N-phenyldibenzo[b,d]furan-2-amine (2.5 g, 5.0 mmol) and sodium hydride (0.34 g, 8.5 mmol) were mixed in 30 mL of dry DMF. The solution was stirred for 1 hour at room temperature. 4-chlorobenzofuro[3,2-d]pyrimidine (1.9 g, 9.5 mmol) was added. The mixture was stirred overnight under nitrogen. The reaction mixture was poured into water and the precipitate was filtered. The residue was then purified by column chromatography using THF:hexane (1:3, v/v) as the eluent. 2.4 g (74%) of a pale yellow solid was obtained as the product.

Photoluminescence (PL) and Device Examples

Photoluminescence and photoluminescence quantum yield (PLQY) experiments were carried out and summarized in Table 2. Poly(methyl methacrylate) (PMMA) doped film (95:5 by weight of PMMA:emitter) were fabricated by solution drop casting on quartz substrates. High PL quatum yields were obtained for Compound S-10-144-H, Compound O-10-144-H and Compound O-10-10-H.

TABLE 2

Compound	PLQY in PMMA film (%)	Em_{max} in PMMA film (nm)
S-10-144-H	75%	452
S-17-144-H	27%	455
O-10-144-H	80%	458
O-10-10-H	69%	476

Solvatochromism experiments were carried out and summarized in Table 3. Photoluminescence spectra of Compound O-10-144-H and Compound O-10-10-H in solvents with different polarity were obtained at room temperature, and bathochromic shift was observed as the polarity of the solvent increased, suggesting the emissive origin of these classes of compound arised from donor-acceptor based CT state.

TABLE 3

Compound	Em_{max} in 3-methylpentane (nm)	Em_{max} in toluene (nm)	Em_{max} in 2-methyltetrahydrofuran (nm)
O-10-144-H	427	468	506
O-10-10-H	437	491	567

Compound O-10-144-H and Compound O-10-10-H were tested as emitters in OLEDs. In the OLED experiment, all device examples were fabricated by high vacuum ($<10^{-7}$ Torr) thermal evaporation. The anode electrode is ~800 Å of indium tin oxide (ITO). The cathode consisted of 10 Å of LiF followed by 1,000 Å of Al. All devices were encapsulated with a glass lid sealed with an epoxy resin in a nitrogen glove box (<1 ppm of H_2O and O_2) and a moisture getter was incorporated inside the package.

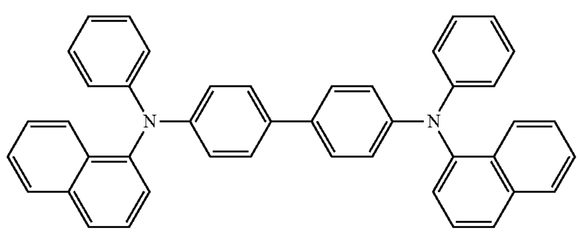
The organic stack of the Device Example 1 consisted of sequentially, from the ITO surface, 100 Å of LG101 (LG Chem, Korea) as the hole injection layer (HIL), 300 Å of Compound A as the hole transporting layer (HTL), 300 Å of Compound B doped with 5% of Compound O-10-10-H as the emissive layer (EML), 50 Å of Compound C as the ETL2 and 400 Å of LG-201 (LG Chem, Korea) as the ETL1. The maximum external quantum efficiency was 4.5%. CIE was 0.167, 0.287.

Device Example 2 was the same as Device Example 1 except that Compound O-10-10-H is replaced with Compound O-10-144-H. The maximum external quantum efficiency is 3.8%. CIE is 0.144, 0.192.

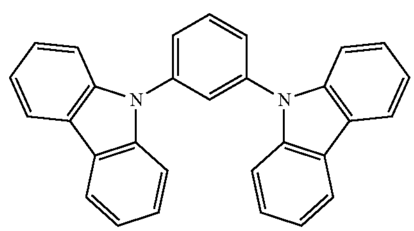
Device Example 3 consisted of sequentially, from the ITO surface, 100 Å of LG101 (LG Chem, Korea) as the hole injection layer (HIL), 300 Å of Compound D as the hole transporting layer (HTL), 300 Å of Compound O-10-144-H as the emissive layer (EML), 50 Å of Compound E as the ETL2 and 400 Å of LG-201 (LG Chem, Korea) as the ETL1. The maximum external quantum efficiency was 6.2%. CIE was 0.199, 0.398.

Device Example 4 consisted of sequentially, from the ITO surface, 100 Å of LG101 (LG Chem, Korea) as the hole injection layer (HIL), 300 Å of Compound D as the hole transporting layer (HTL), 300 Å of Compound B doped with 10% of Compound O-10-144-H as the emissive layer (EML), 400 Å of Compound F as the ETL. The maximum external quantum efficiency was 11.0%. CIE was 0.141, 0.182. The high device external quamtum efficiency (EQE) of Device Examples 1 and 2 shows that donor-acceptor compounds of Formula 1 are efficient emitters for OLEDs. The high device external quamtum efficiency also suggests that triplet excition may be converted into emissive singlet excition via the delayed fluorescence mechanism.

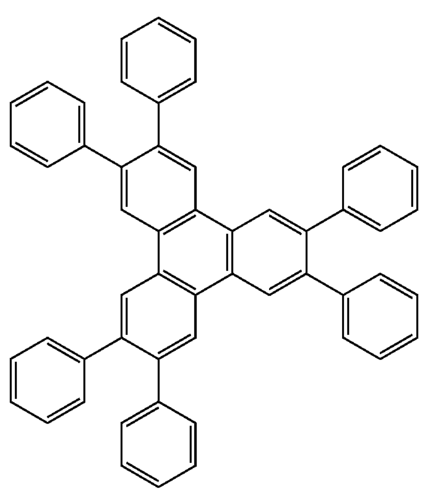
Compound A



Compound B



Compound C



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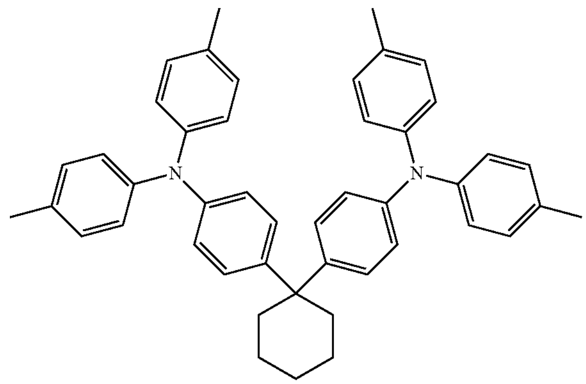
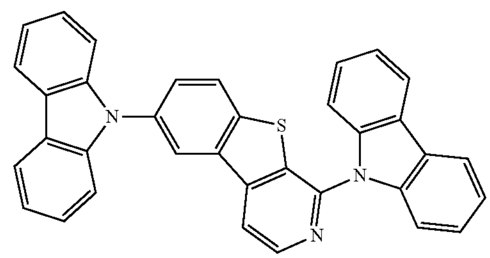
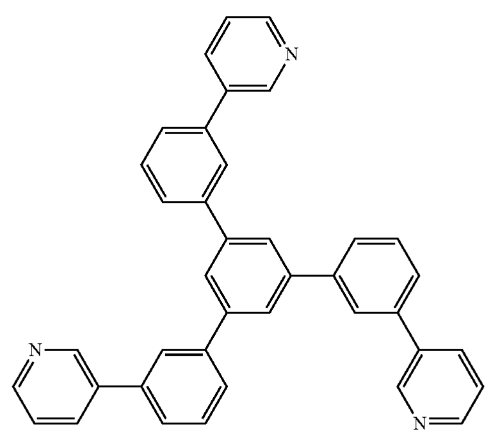
Compound D



Compound E



Compound F

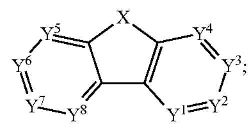


It is understood that the various embodiments described herein are by way of example only, and are not intended to limit the scope of the invention. For example, many of the materials and structures described herein may be substituted with other materials and structures without deviating from the spirit of the invention. The present invention as claimed may therefore include variations from the particular examples and preferred embodiments described herein, as will be apparent to one of skill in the art. It is understood that various theories as to why the invention works are not intended to be limiting.

We claim:

1. A compound having the formula:

Formula 1



wherein each of Y^1 to Y^8 is C—R or N;

wherein at least two of Y^1 to Y^8 is N;

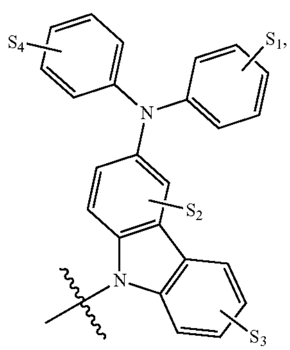
wherein at least one of Y^1 to Y^8 is C—R;

X is O, S, or Se;

each R is independently selected from the group consisting of hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrile, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof;

wherein at least one of the R is selected from the group consisting of

D3



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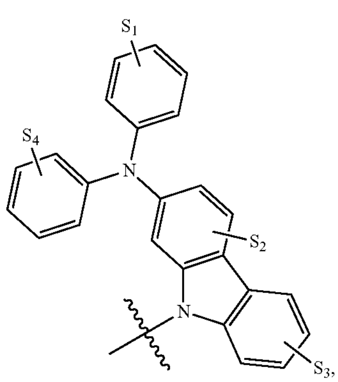

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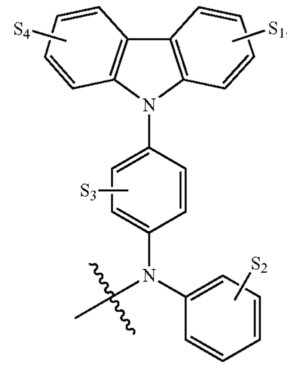
D5



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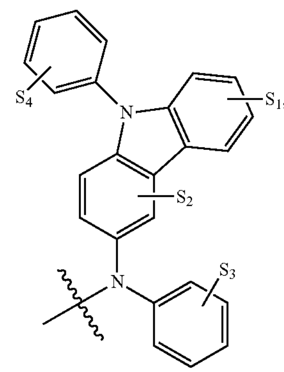

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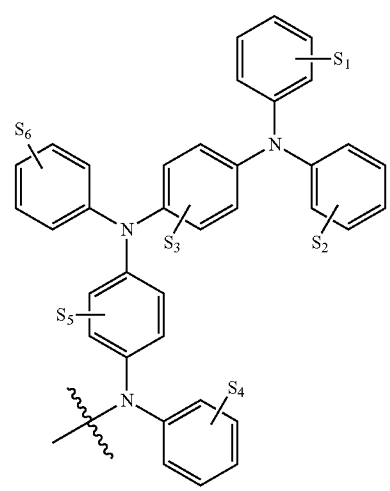

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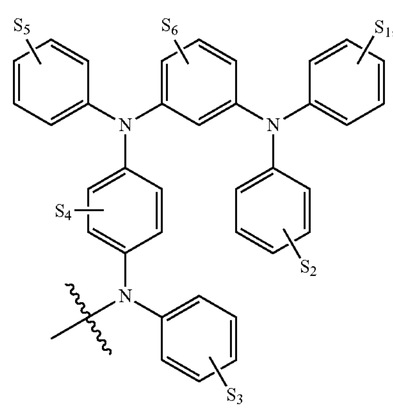

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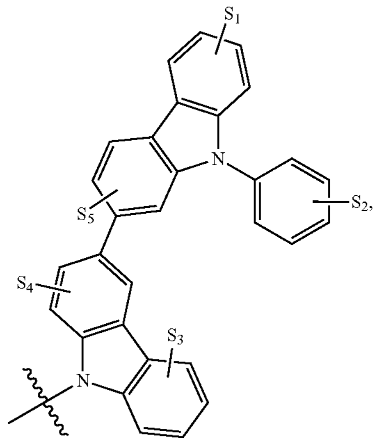

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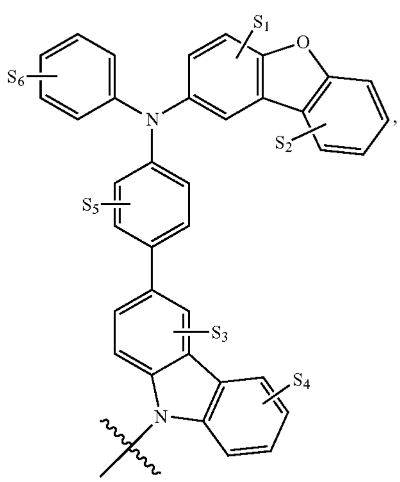

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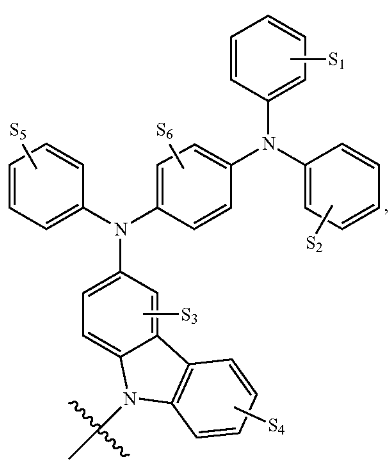

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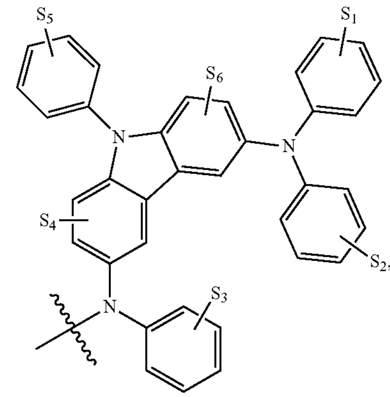

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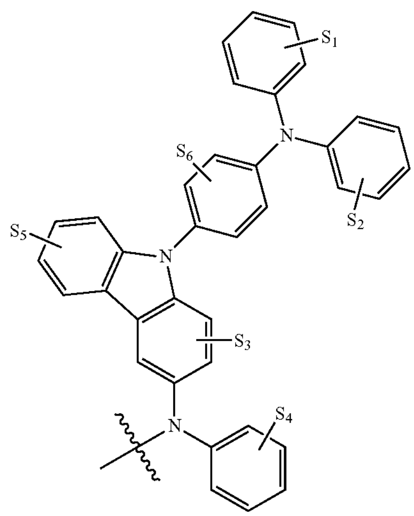

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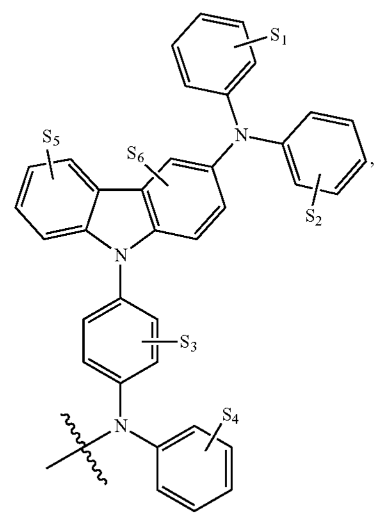

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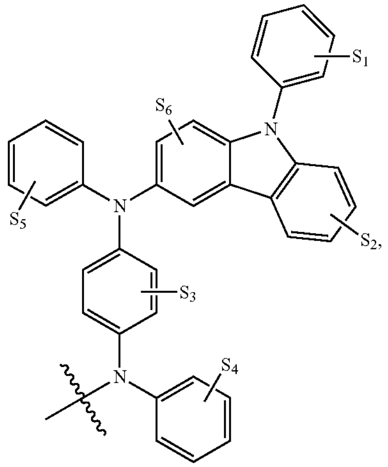

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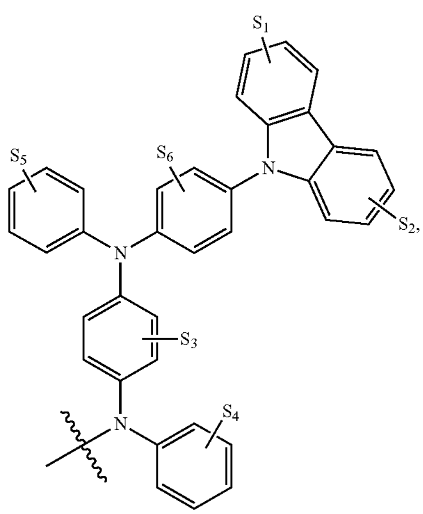

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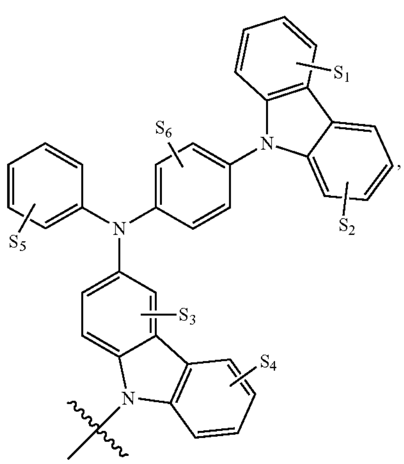

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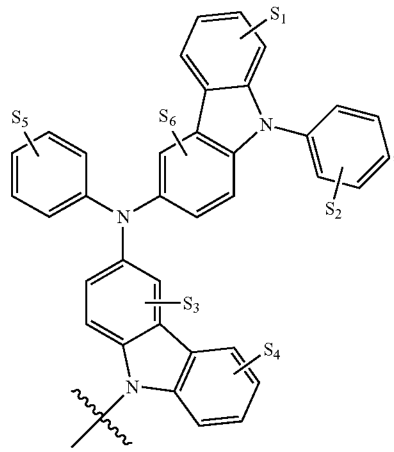

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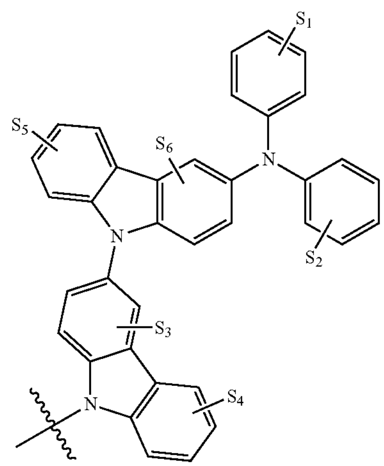

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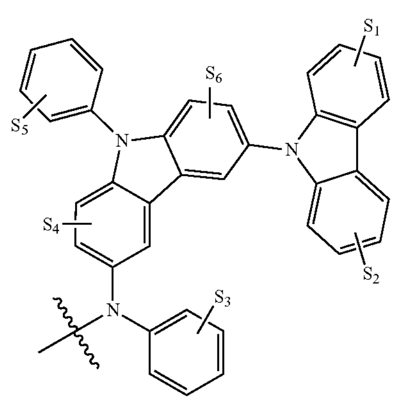

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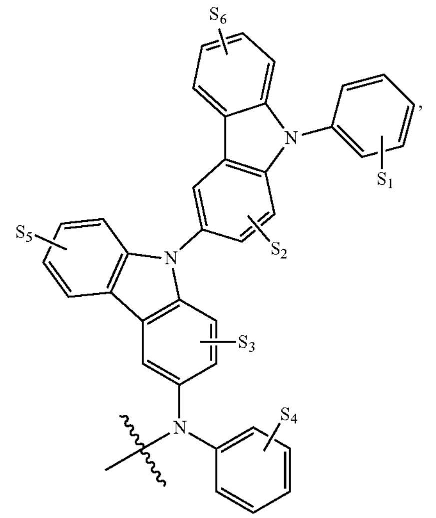

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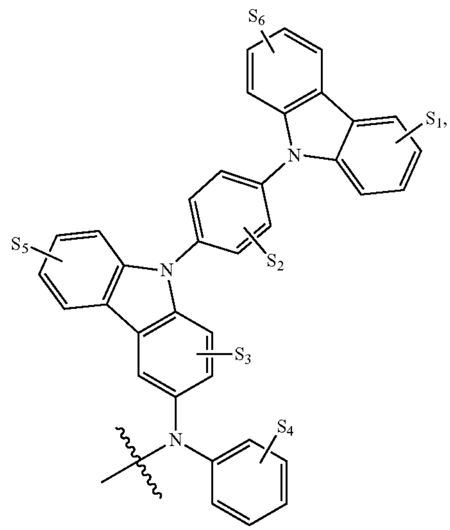

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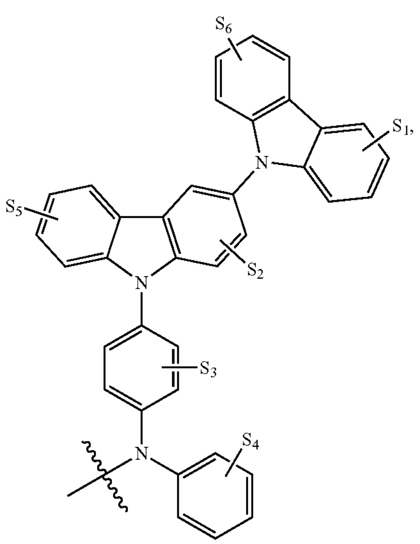

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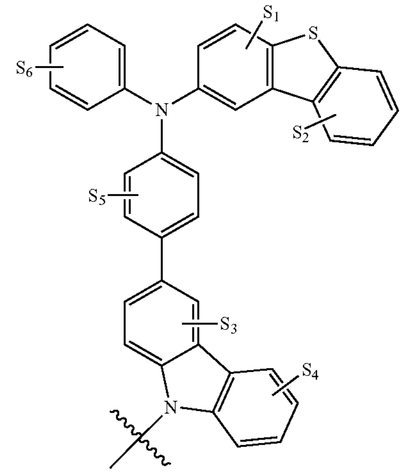

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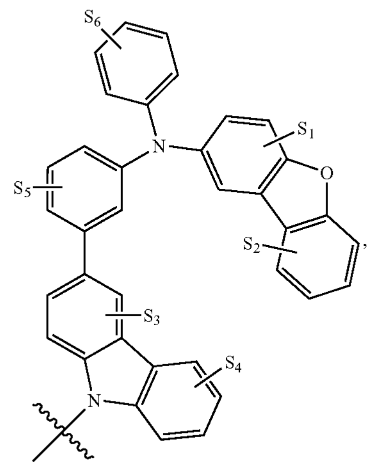

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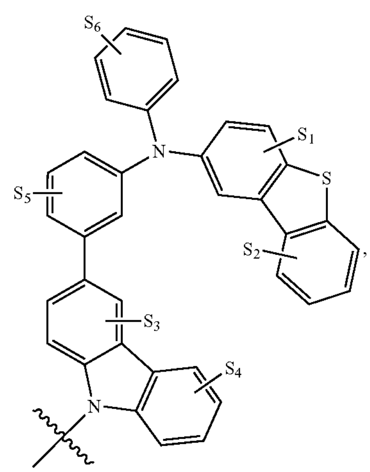

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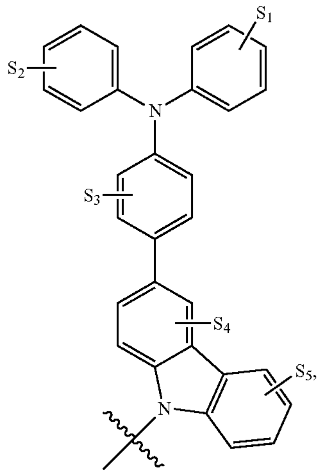

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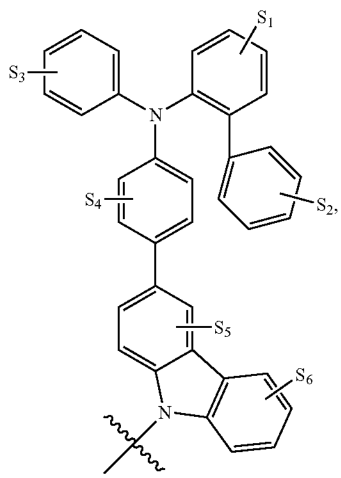

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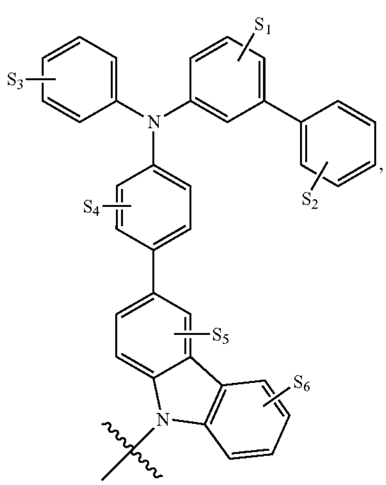

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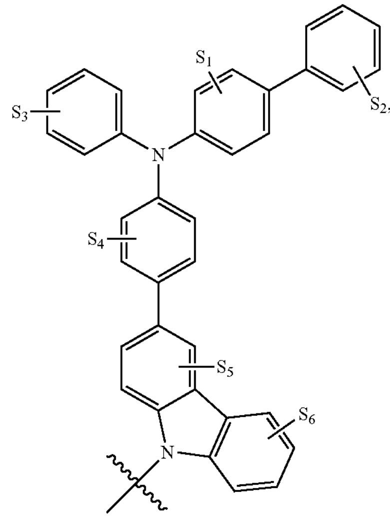

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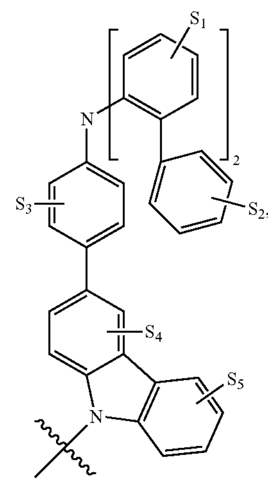

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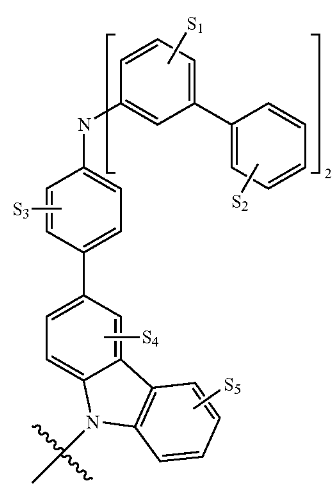

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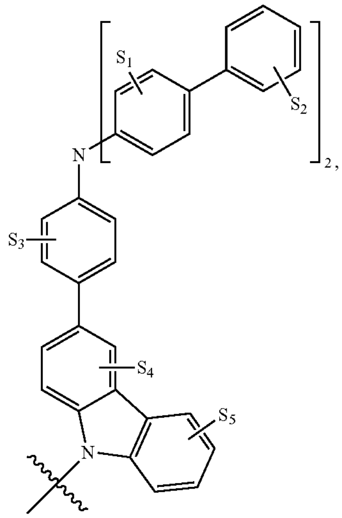

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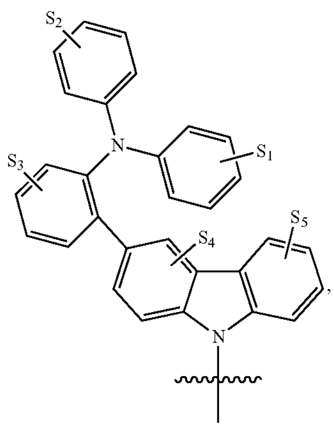

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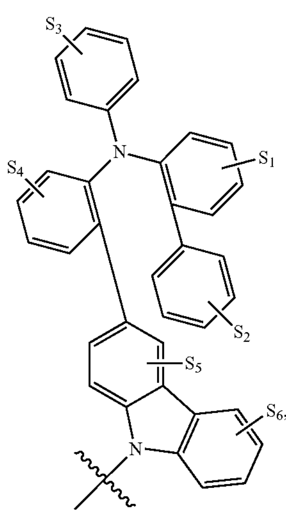

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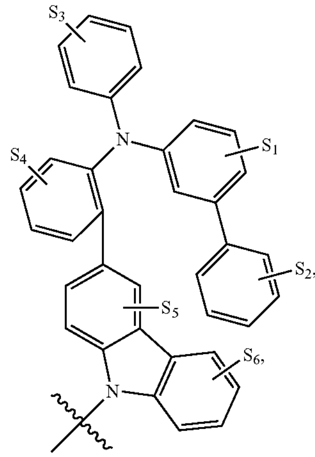

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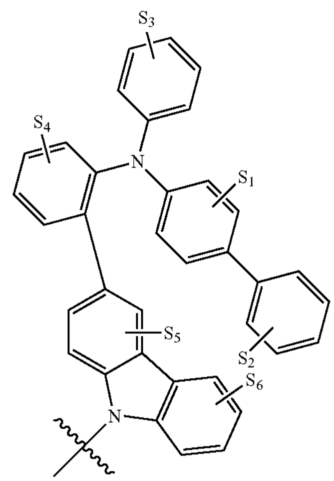

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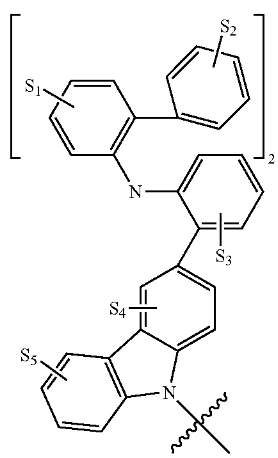

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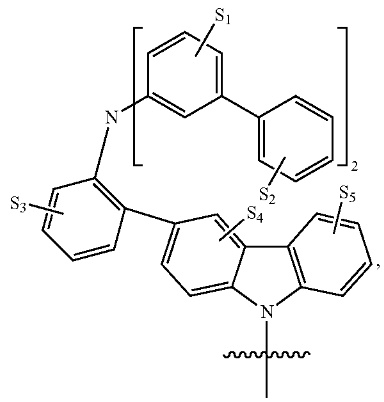

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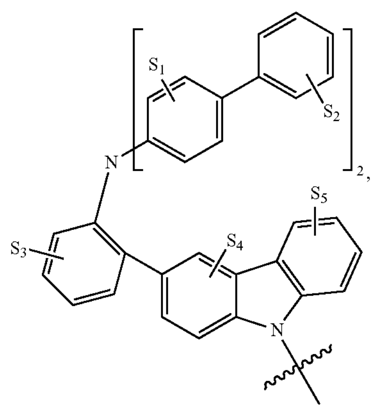

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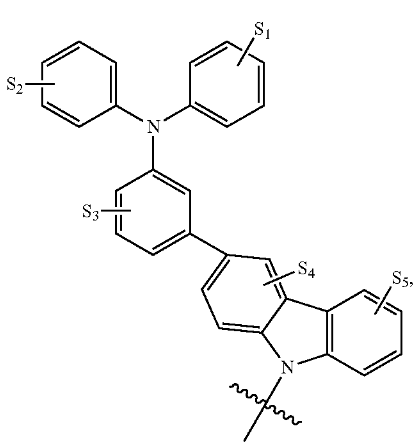

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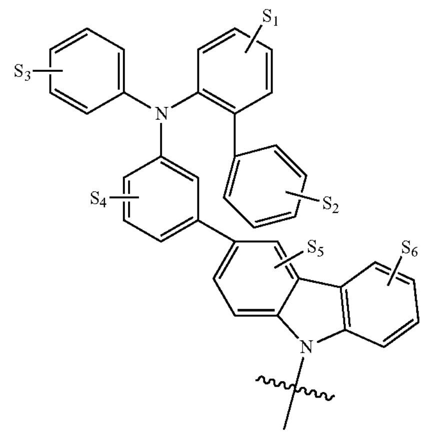

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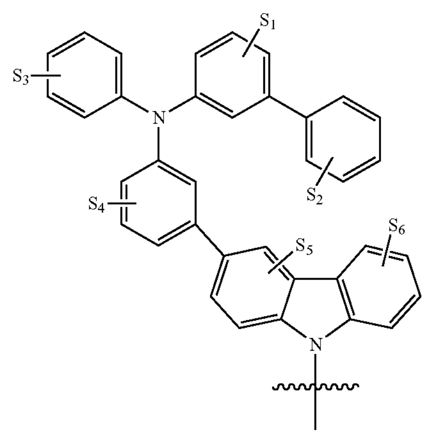

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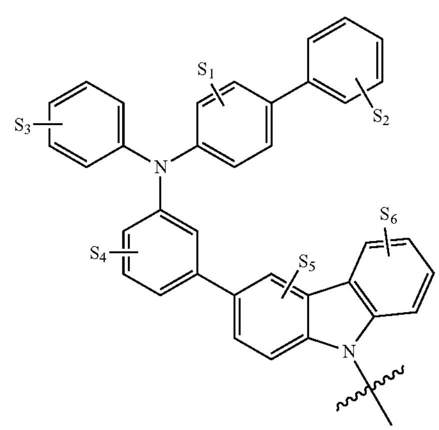

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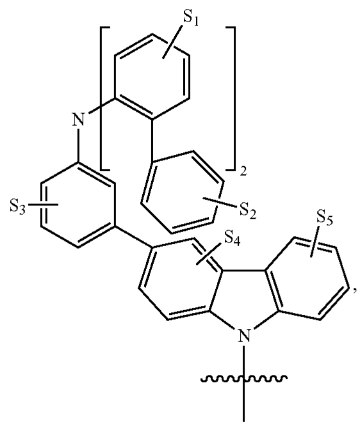

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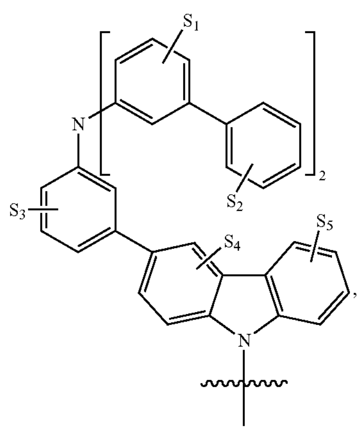

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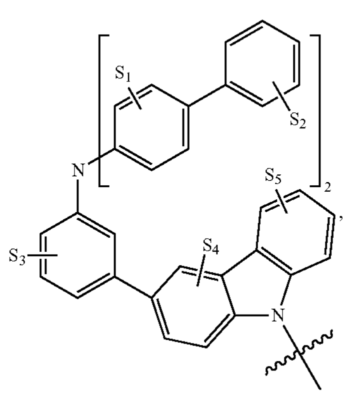

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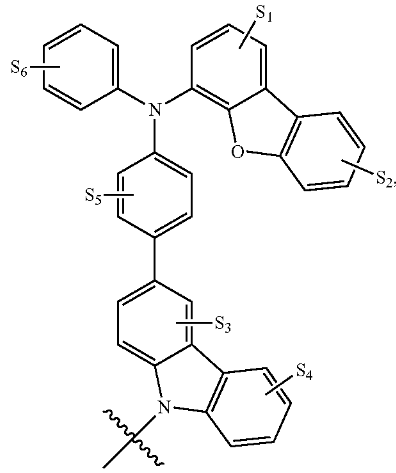

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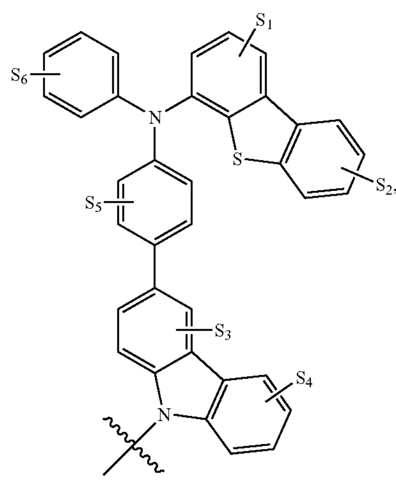

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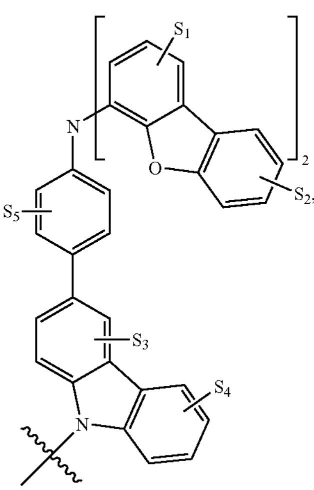

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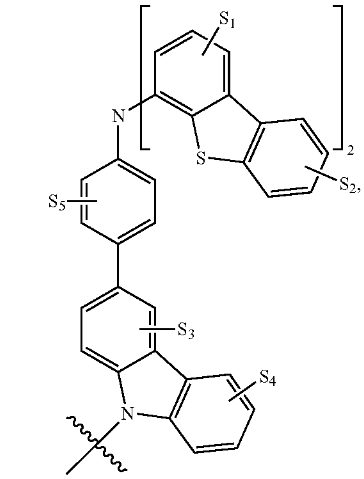

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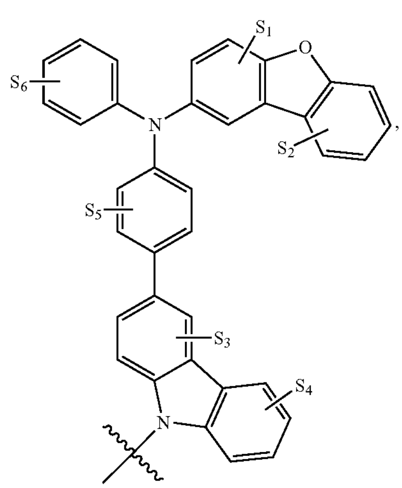

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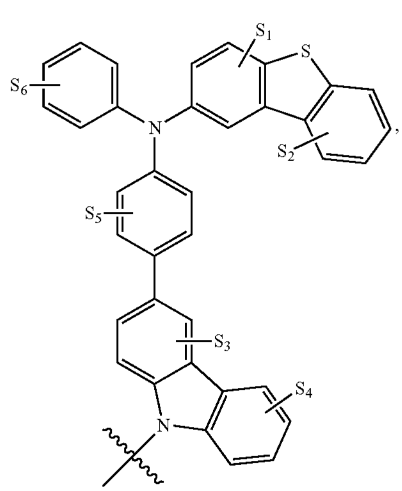

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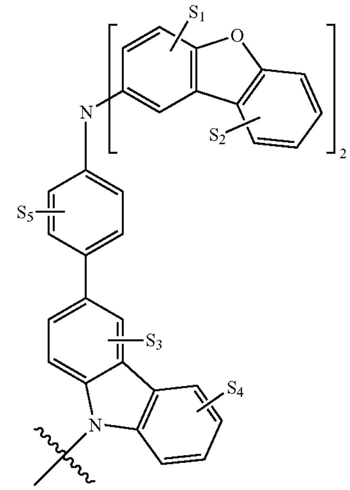

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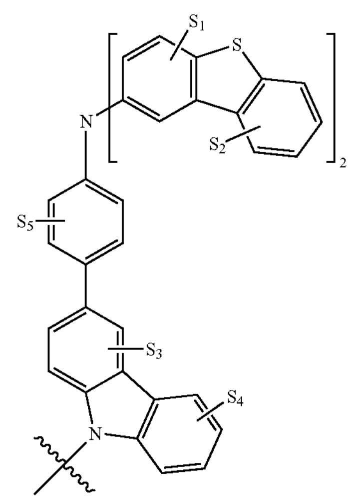

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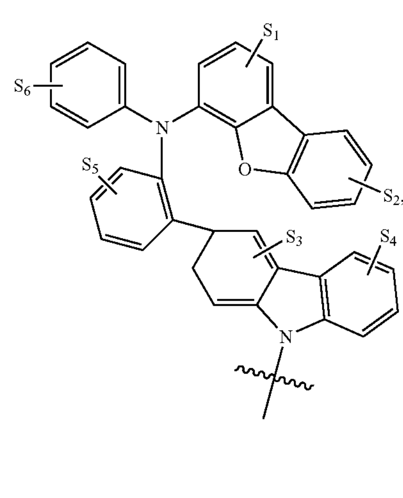

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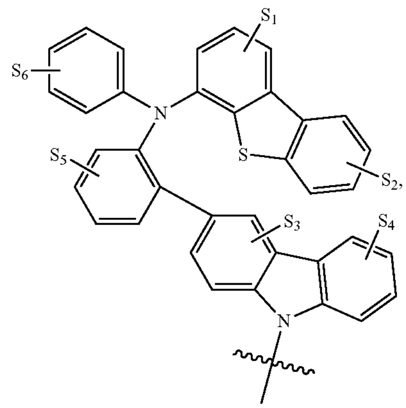

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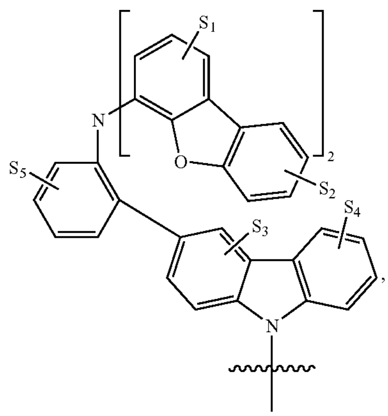

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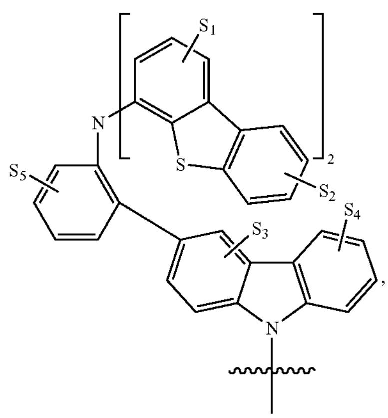

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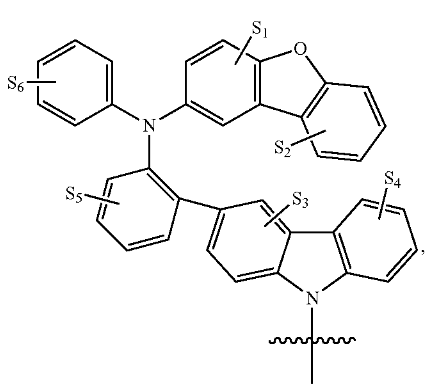

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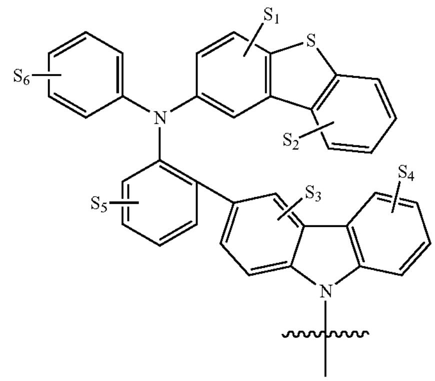
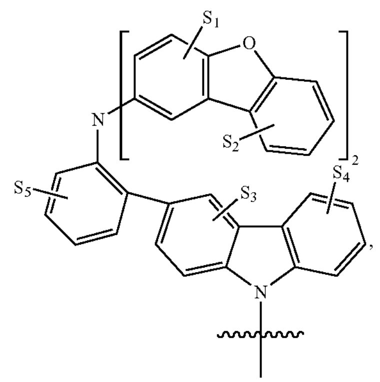
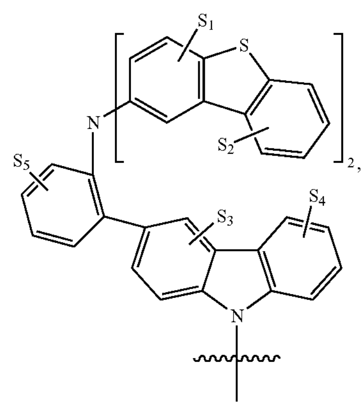


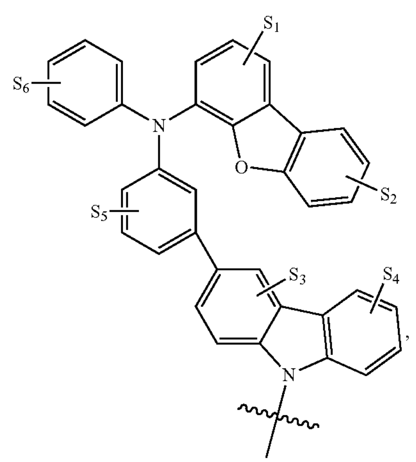
D68



D69



D70



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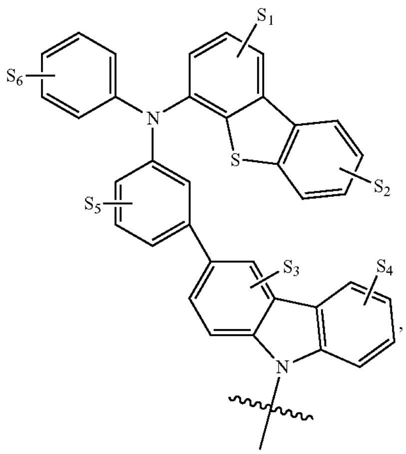
D71



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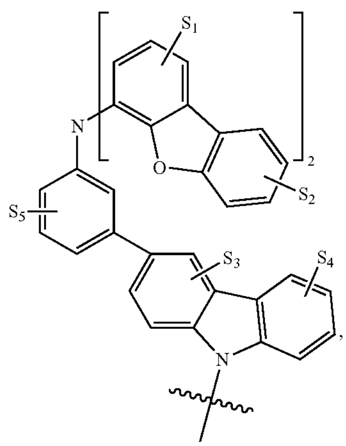

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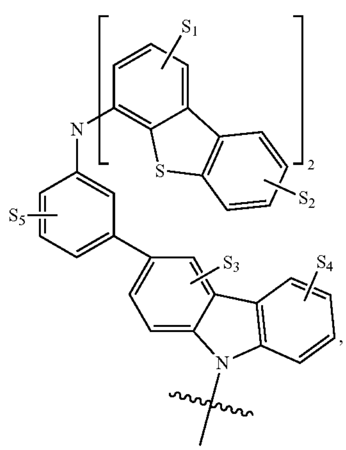

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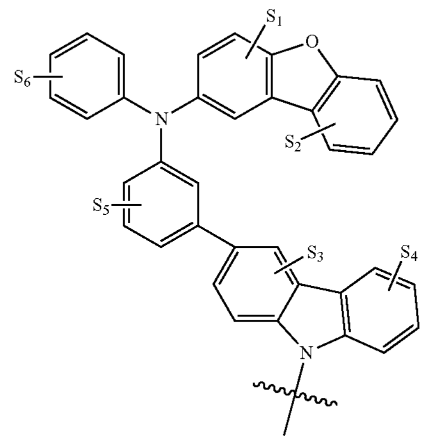
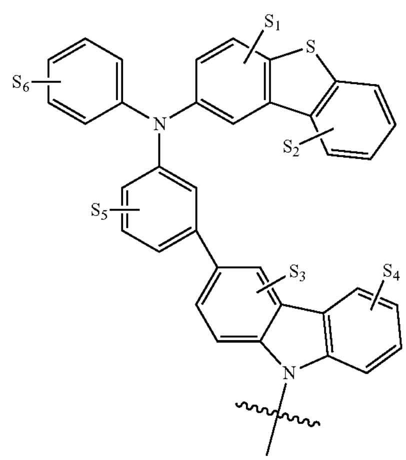
D74



D75



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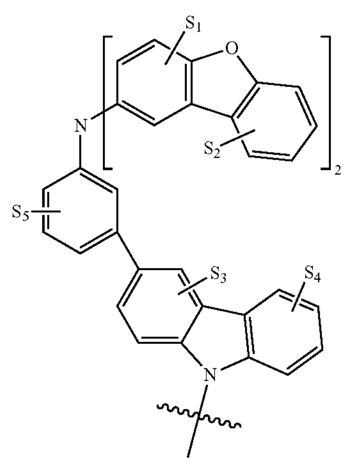

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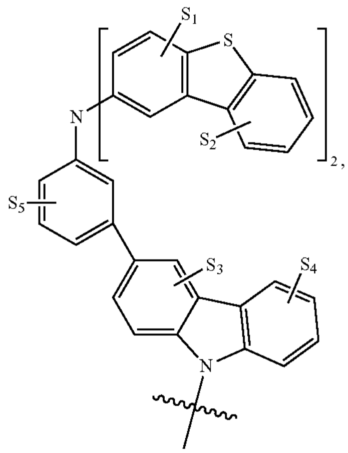

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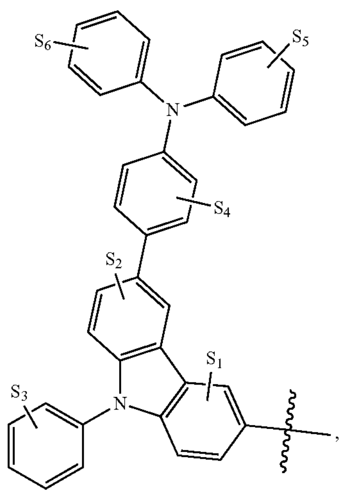

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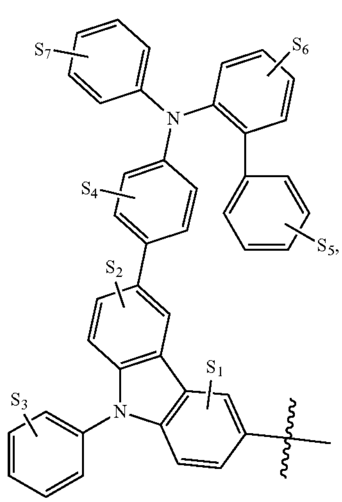

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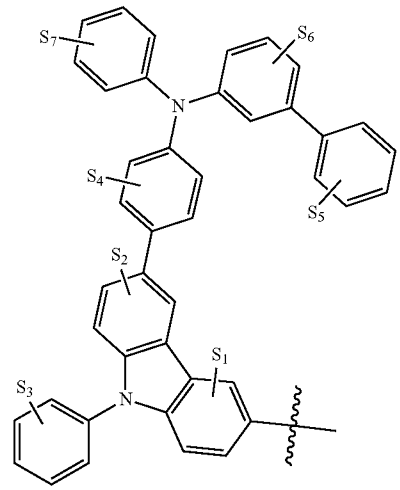

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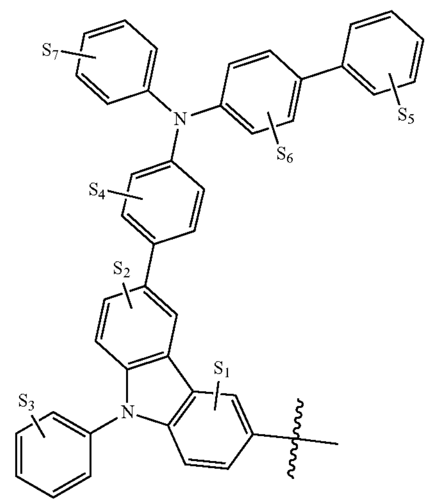

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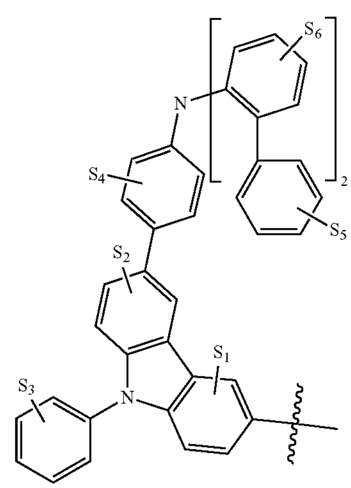

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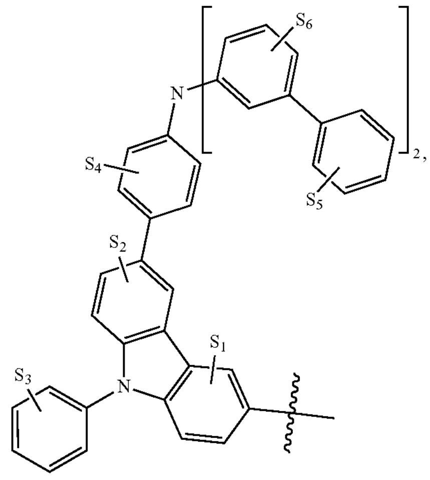

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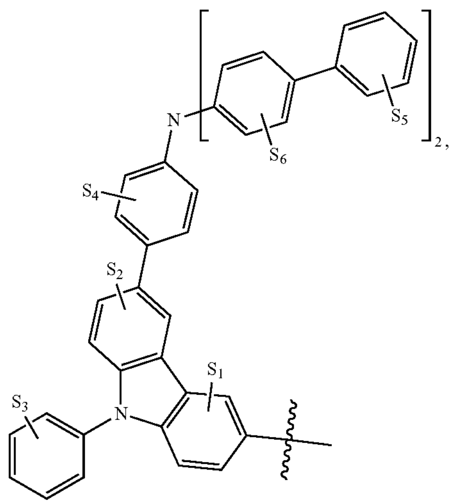

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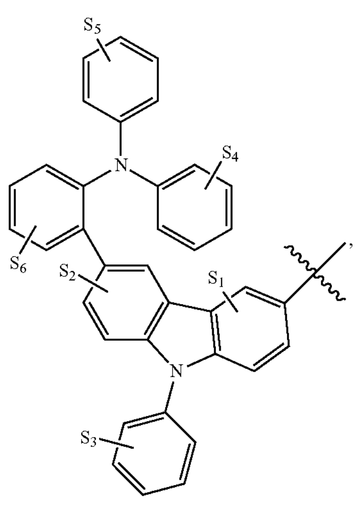

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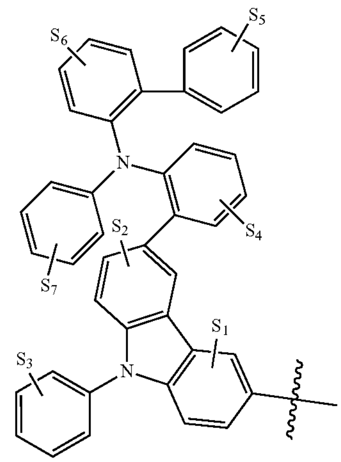

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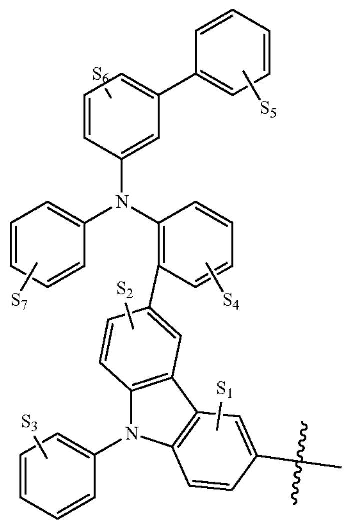

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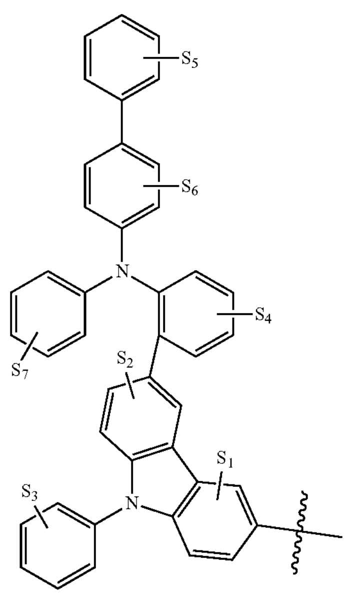

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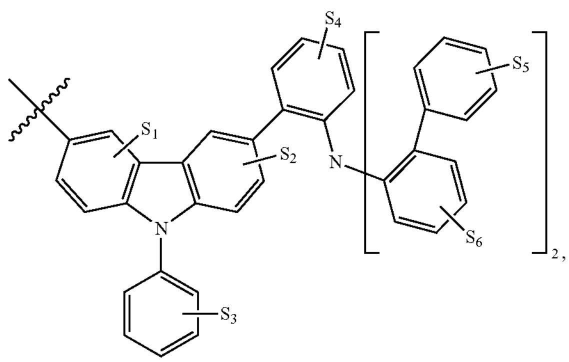

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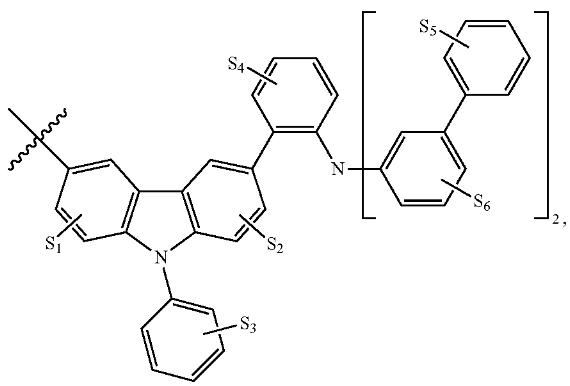

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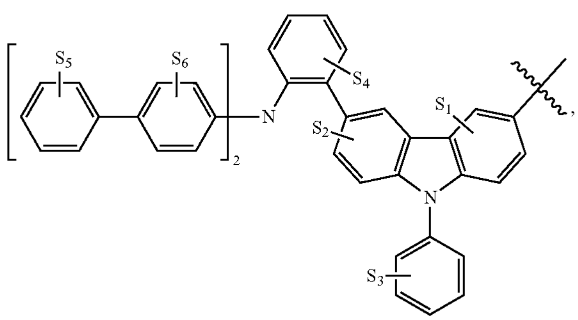

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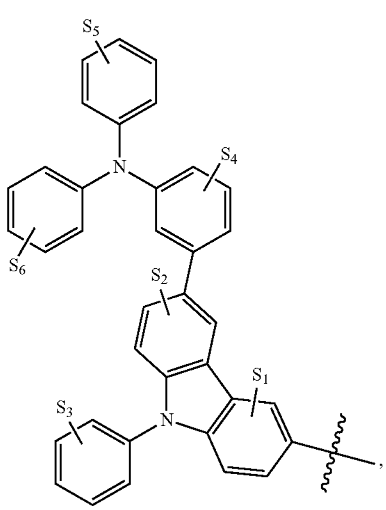

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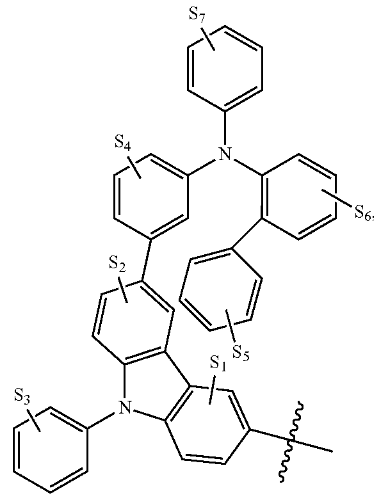

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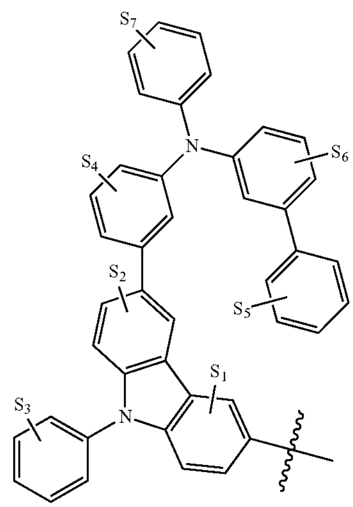

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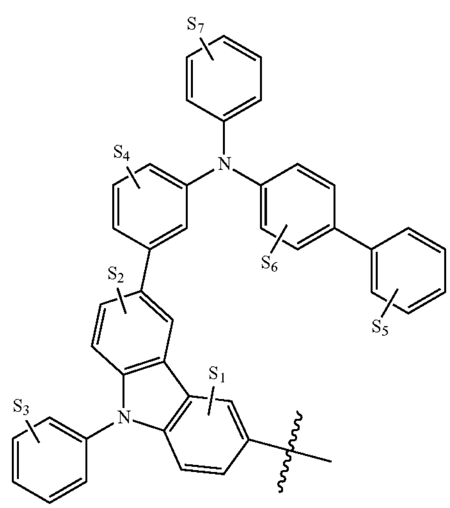

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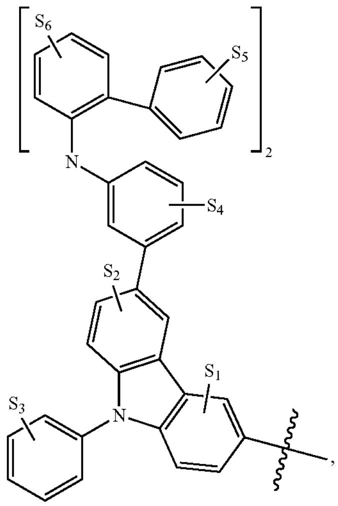

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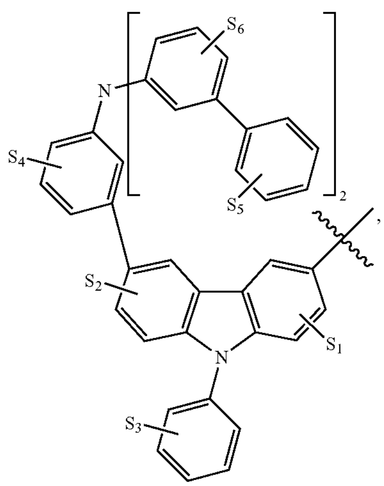

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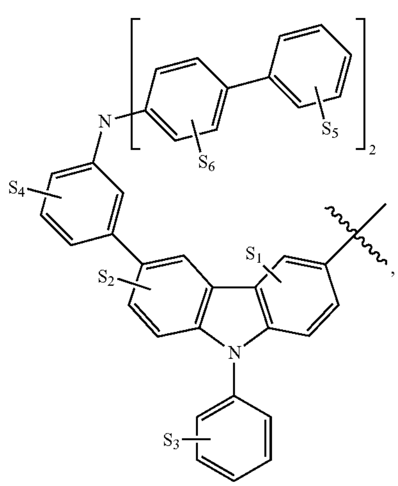

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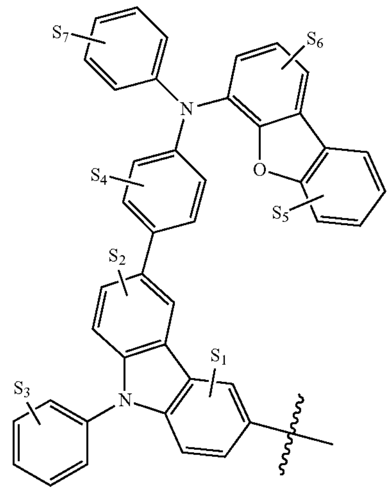

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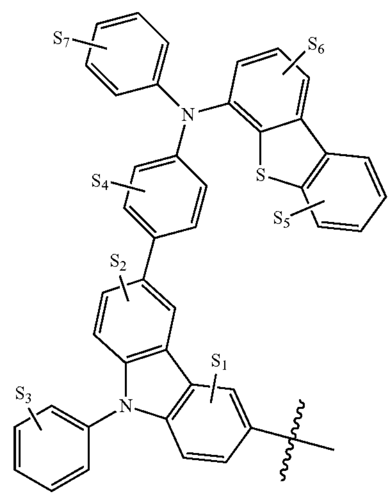

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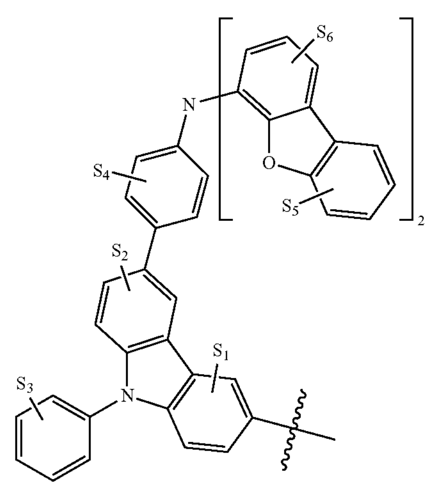

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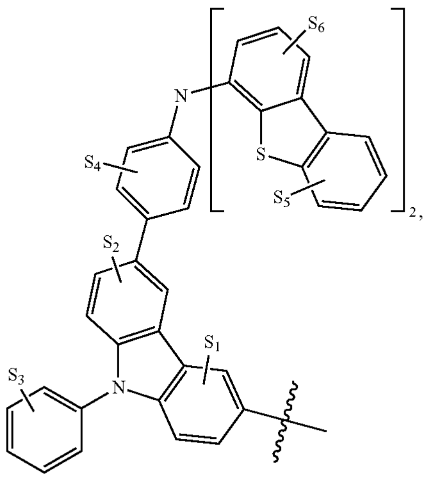

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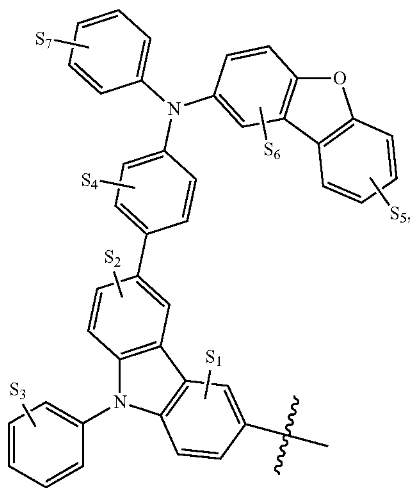

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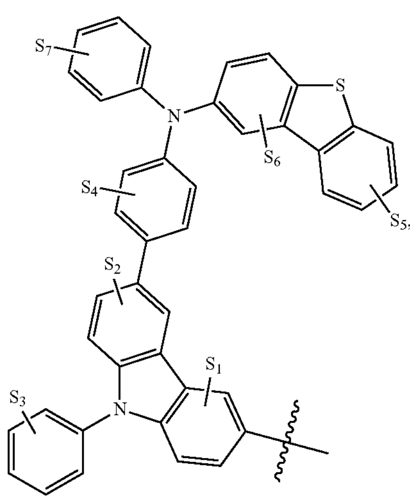

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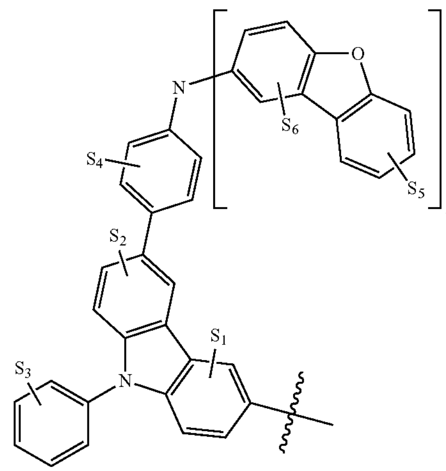

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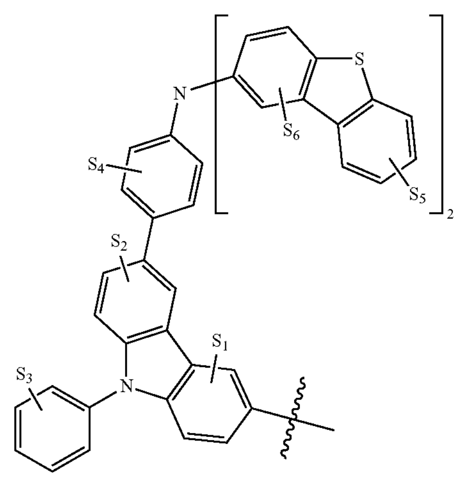

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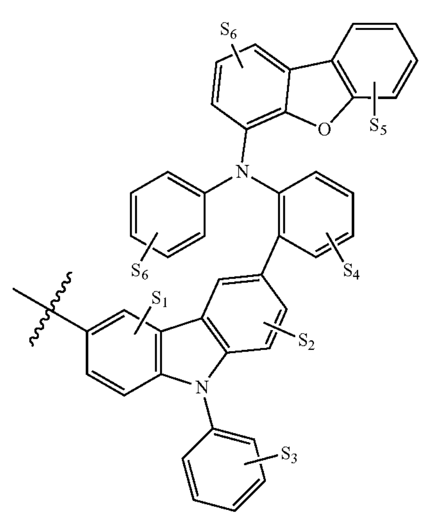

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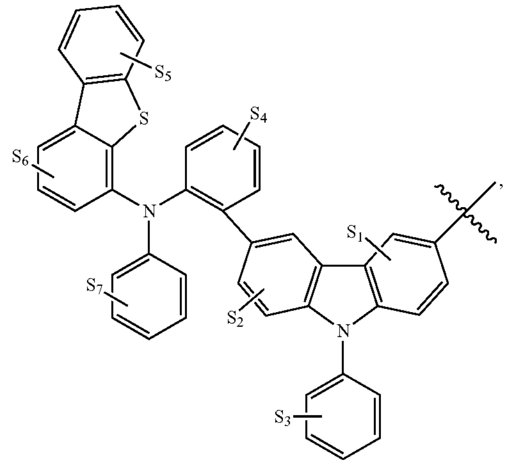

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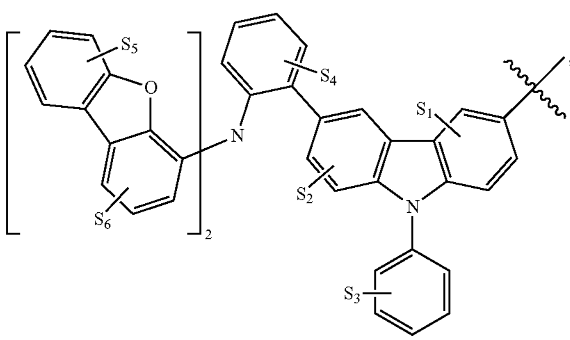

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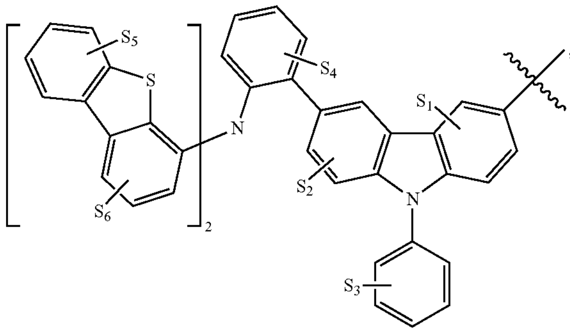

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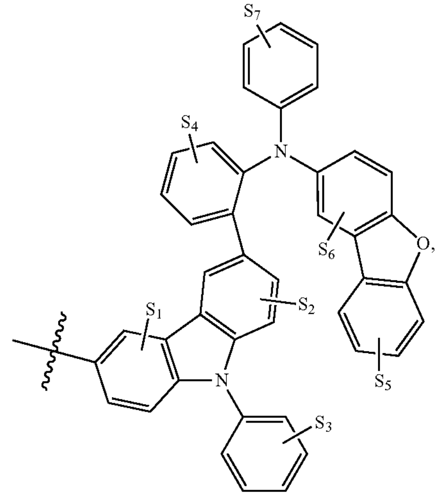

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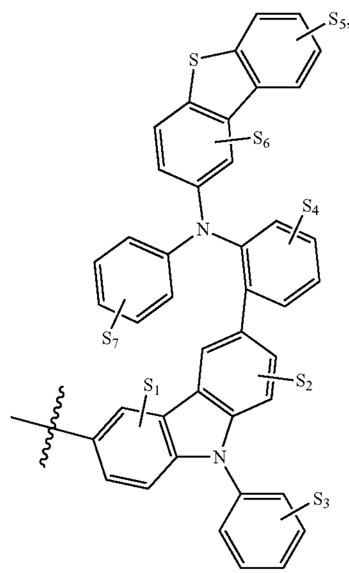

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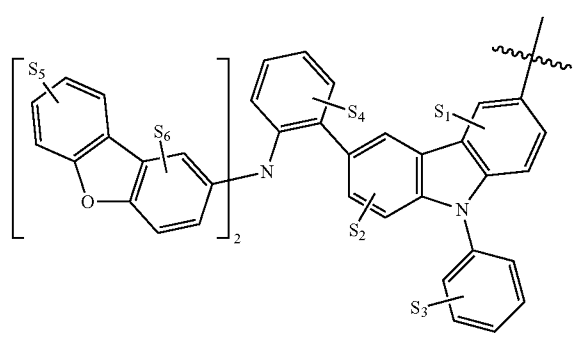

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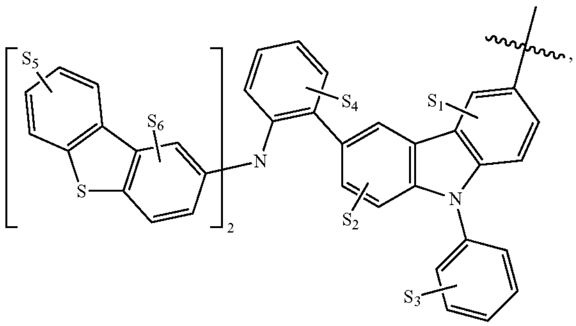

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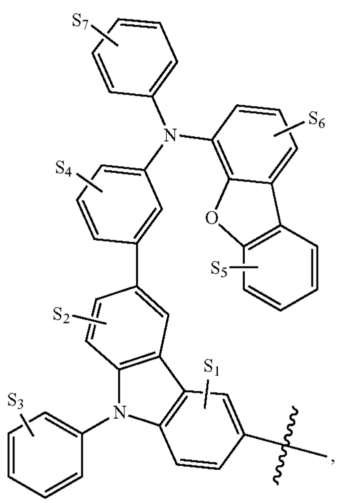

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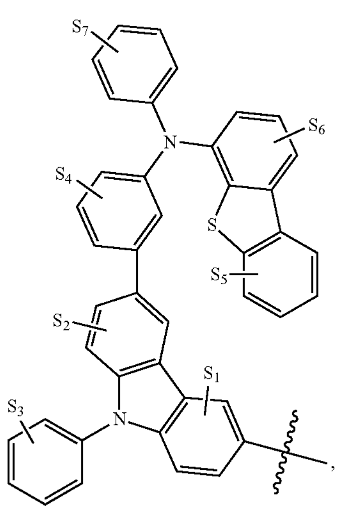

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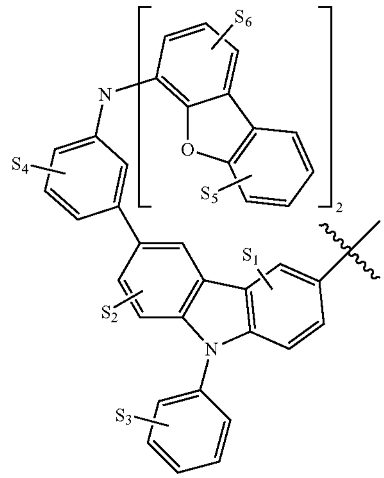

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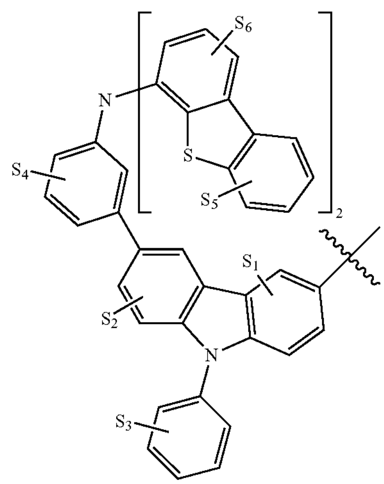

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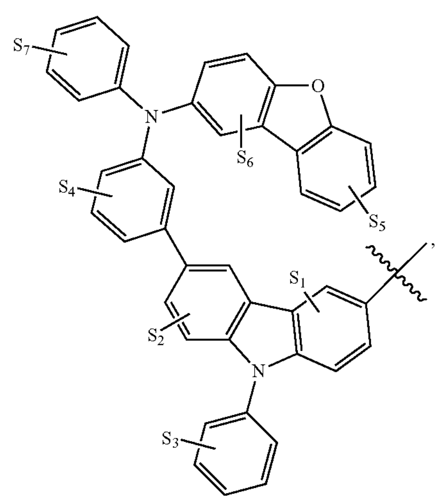

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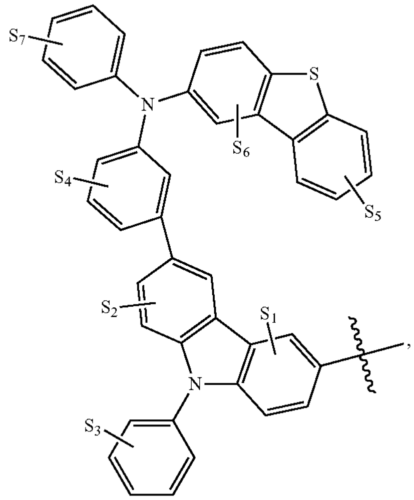

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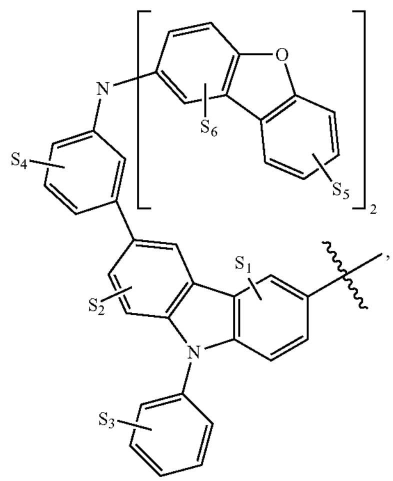

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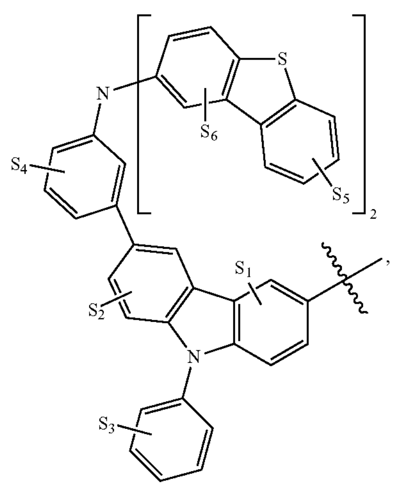

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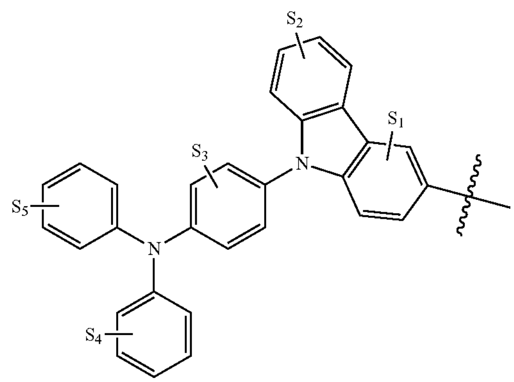

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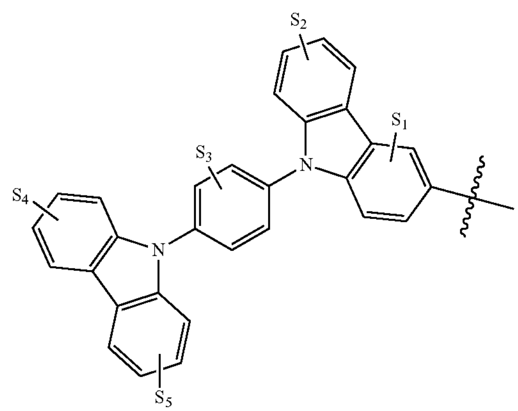

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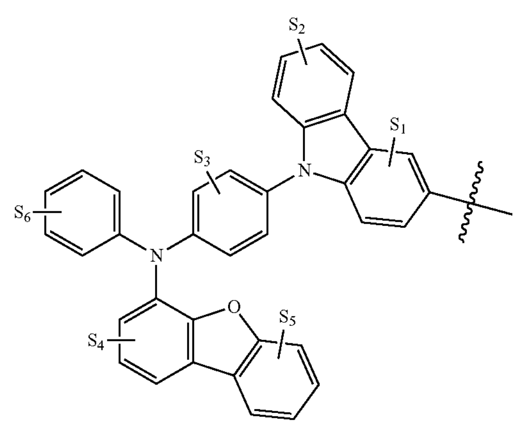

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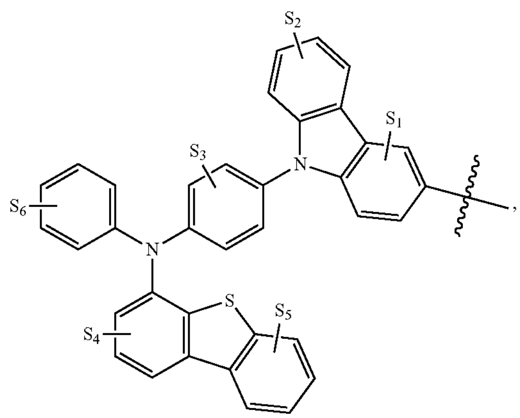

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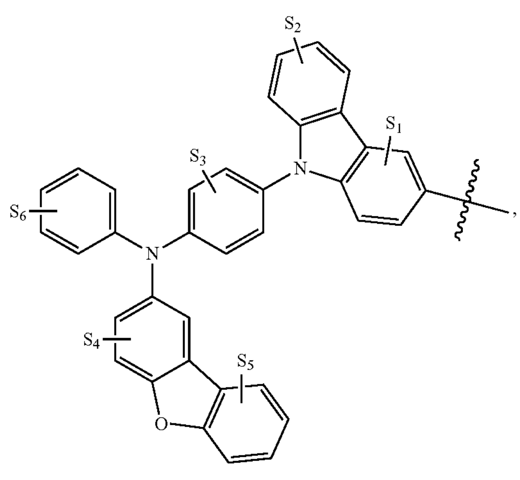

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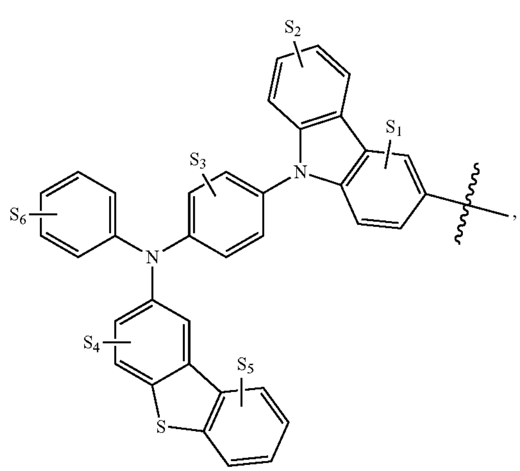

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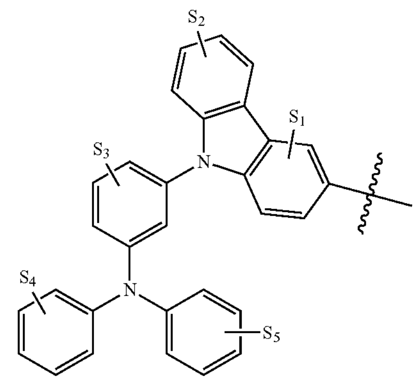

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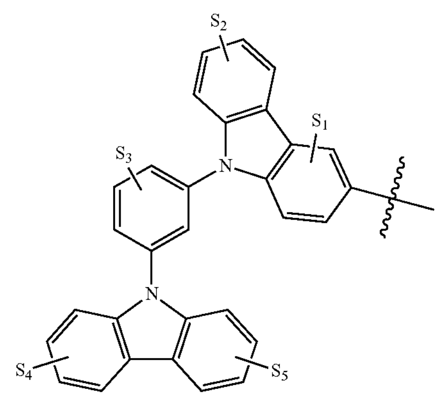

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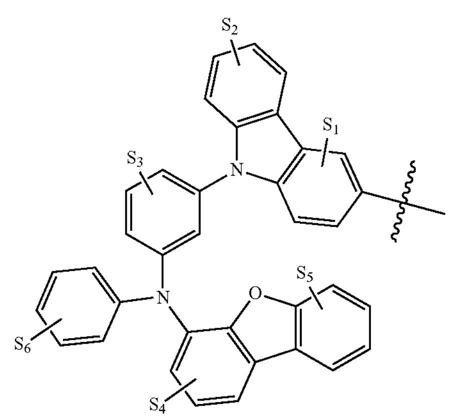

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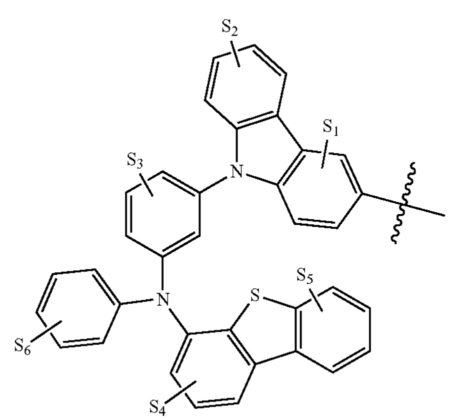

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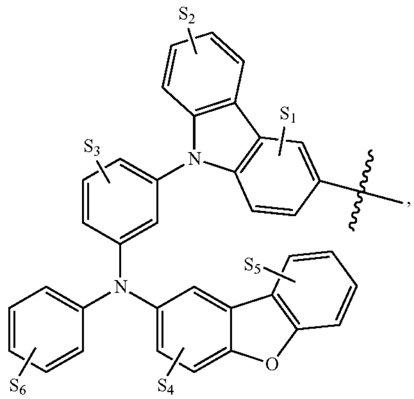

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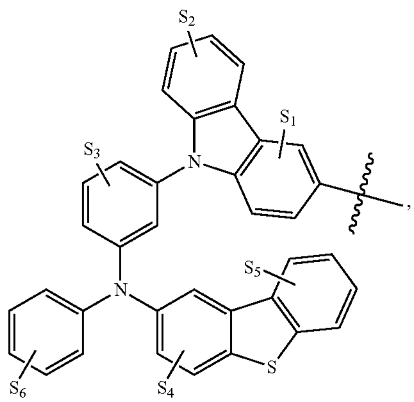

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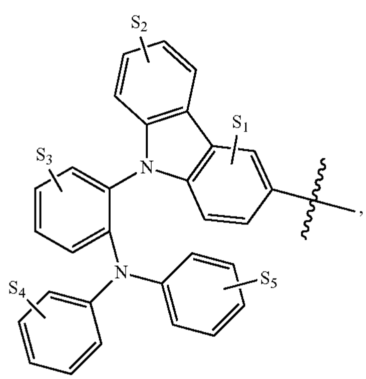

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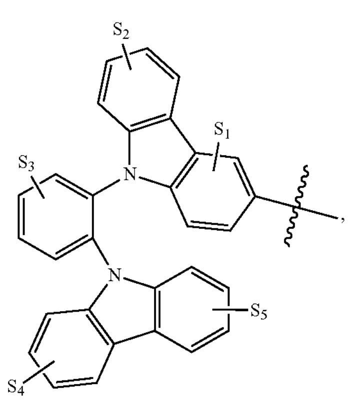

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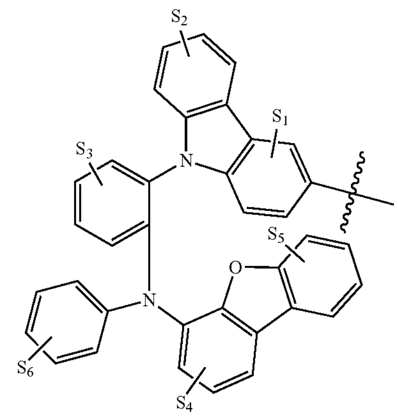

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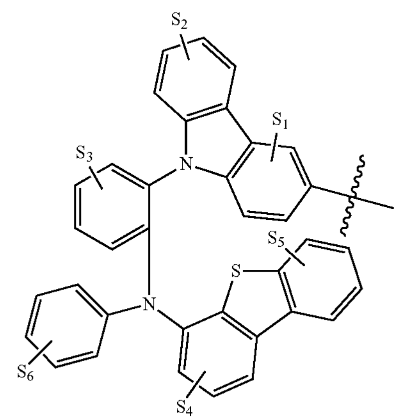

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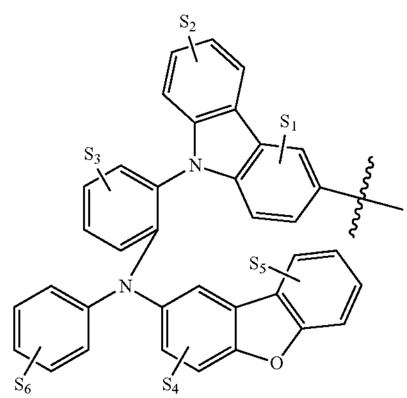
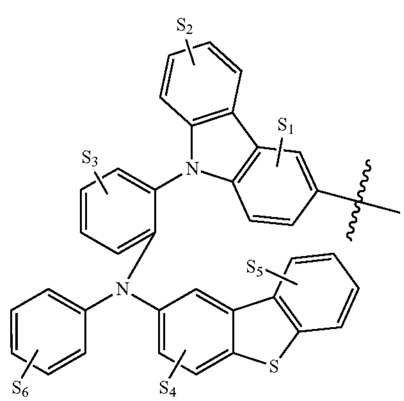


and

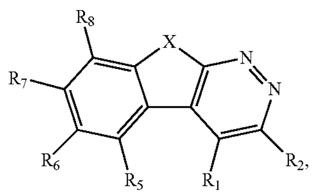
D140



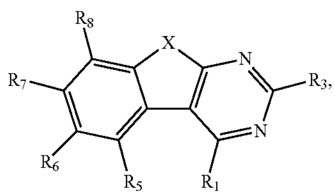
wherein S_1 to S_7 represent mono, di, tri, tetra or penta substitutions with hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrile, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof.

2. The compound of claim **1**, wherein the compound is selected from the group consisting of

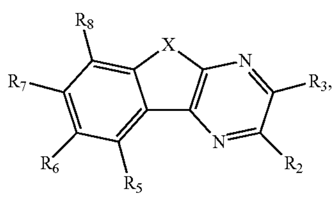
Formula 2



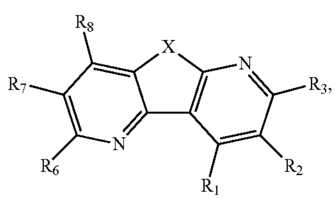
Formula 3



Formula 4



Formula 5



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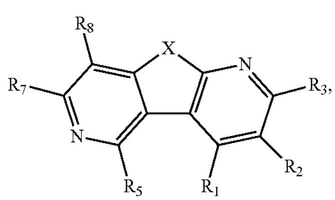

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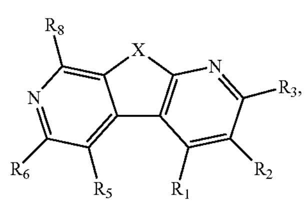

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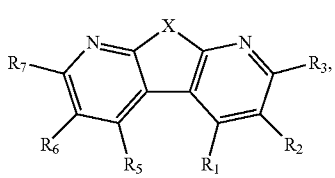

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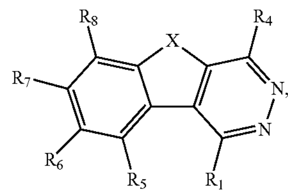
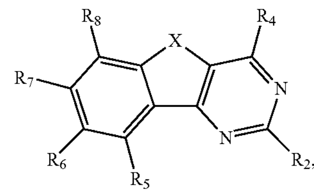
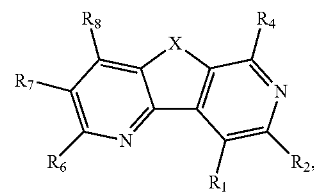
Formula 9



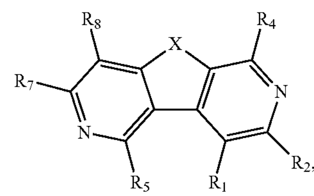
Formula 10



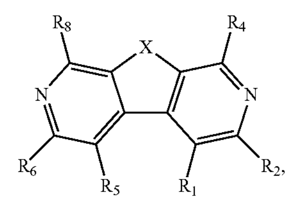
Formula 11



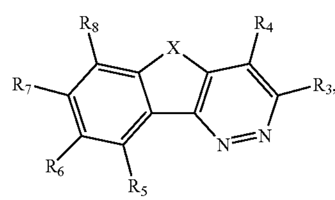
Formula 12



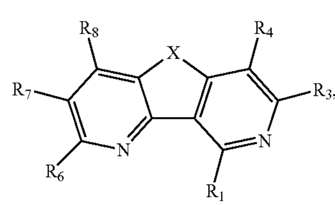
Formula 13



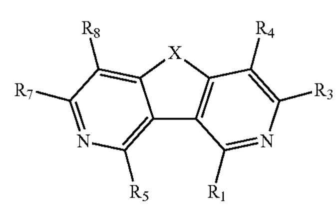
Formula 14



Formula 15

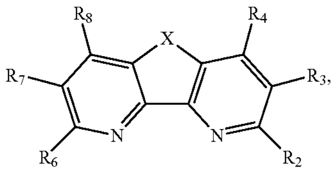


Formula 16



and

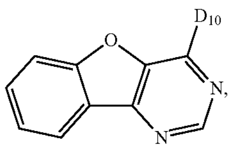
Formula 17



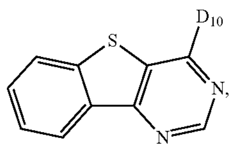
wherein at least one of R_1-R_8 is selected from the group consisting of D1 to D140.

3. The compound of claim **1**, wherein the compound is selected from the group consisting of:

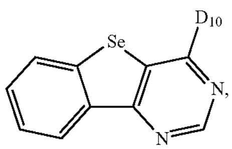
Compound O-10-10



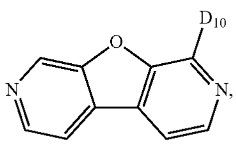
Compound S-10-10



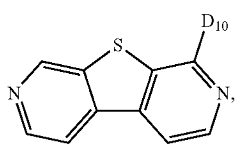
Compound Se-10-10



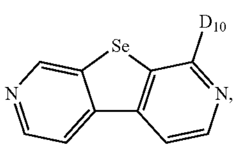
Compound O-13-10



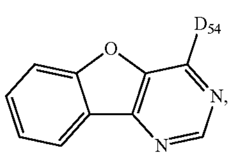
Compound S-13-10



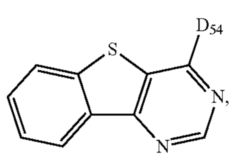
Compound Se-13-10



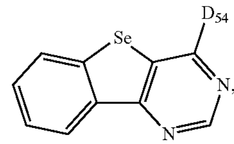
Compound O-10-54



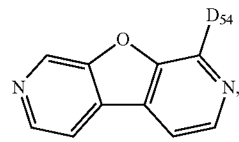
Compound S-10-54



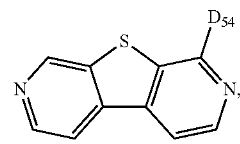
Compound Se-10-54



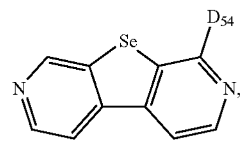
Compound O-13-54



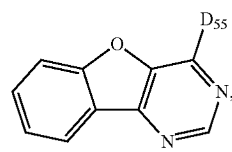
Compound S-13-54



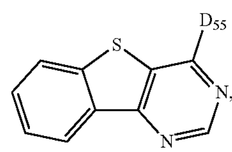
Compound Se-13-54



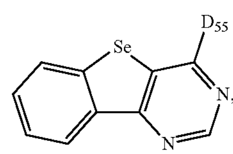
Compound O-10-55



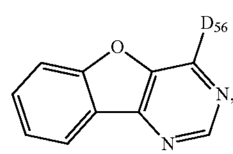
Compound S-10-55



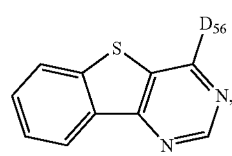
Compound Se-10-55



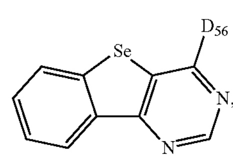
Compound O-10-56



Compound S-10-56



Compound Se-10-56



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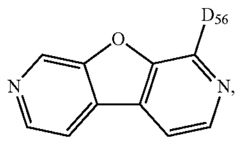
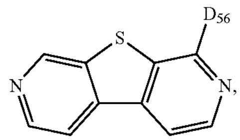
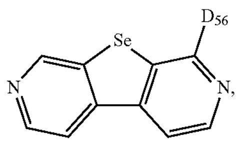
Compound O-13-56



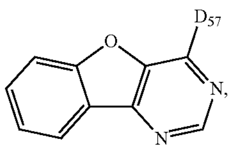
Compound S-13-56



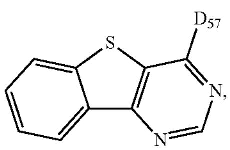
Compound Se-13-56



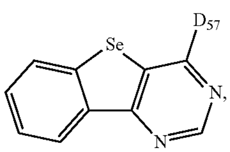
Compound O-10-57



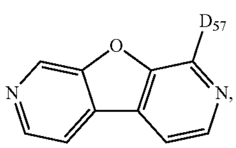
Compound S-10-57



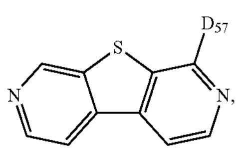
Compound Se-10-57



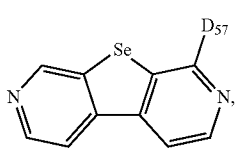
Compound O-13-57



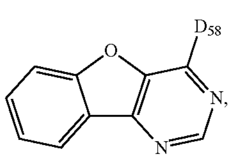
Compound S-13-57



Compound Se-13-57



Compound O-10-58



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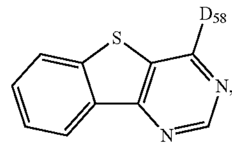
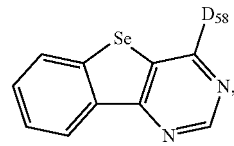
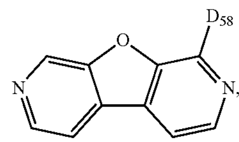
Compound S-10-58



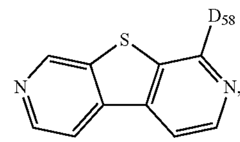
Compound Se-10-58



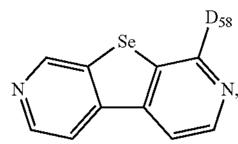
Compound O-13-58



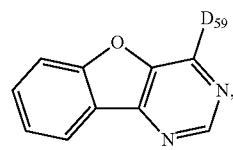
Compound S-13-58



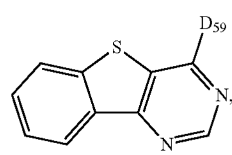
Compound Se-13-58



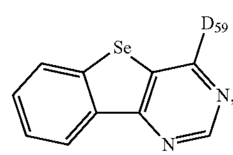
Compound O-10-59



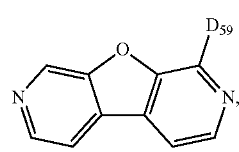
Compound S-10-59



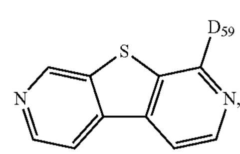
Compound Se-10-59



Compound O-13-59



Compound S-13-59



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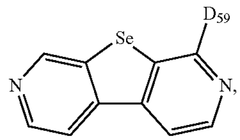
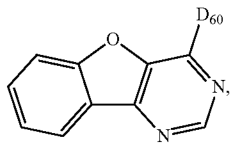
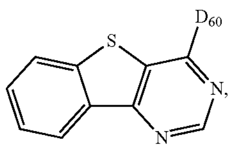
Compound Se-13-59



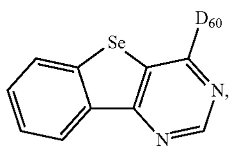
Compound O-10-60



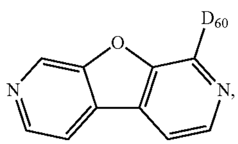
Compound S-10-60



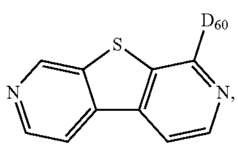
Compound Se-10-60



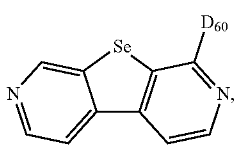
Compound O-13-60



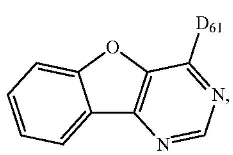
Compound S-13-60



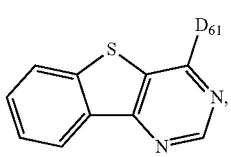
Compound Se-13-60



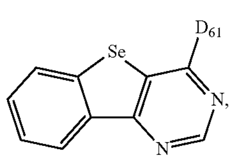
Compound O-10-61



Compound S-10-61



Compound Se-10-61



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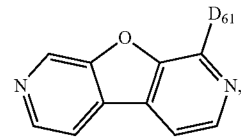
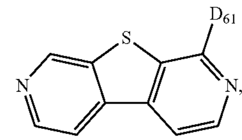
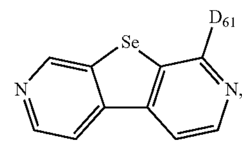
Compound O-13-61



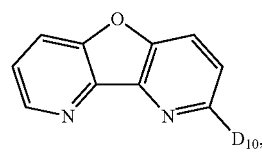
Compound S-13-61



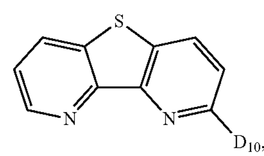
Compound Se-13-61



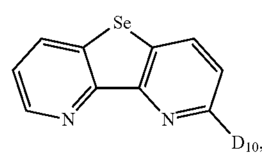
Compound O-17-10



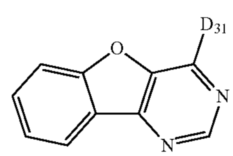
Compound S-17-10



Compound Se-17-10

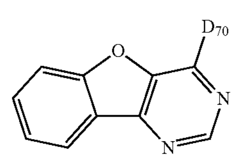


Compound O-10-31



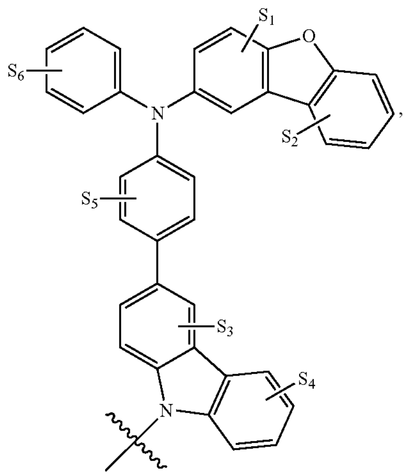
and

Compound O-10-70

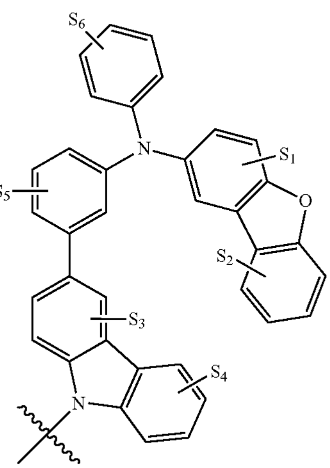


wherein D10, D31, D54, D55, D56, D57, D58, D59, D60, D70 and D61 are

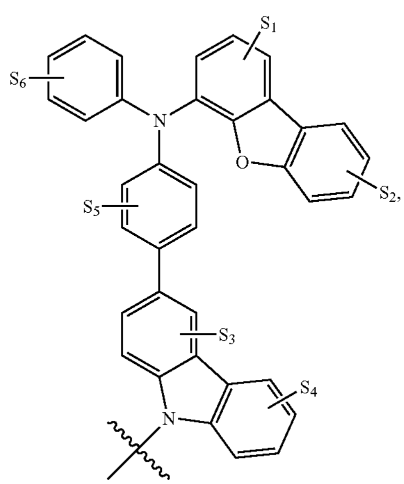
D10



D31



D54



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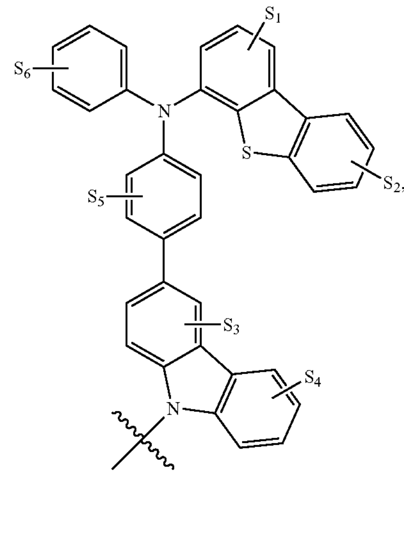
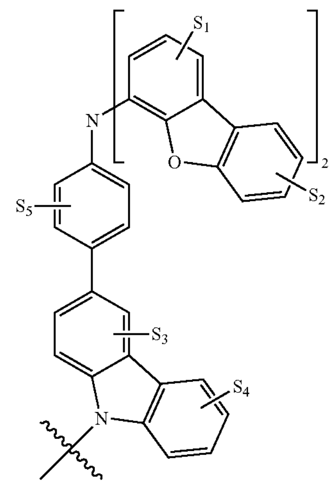
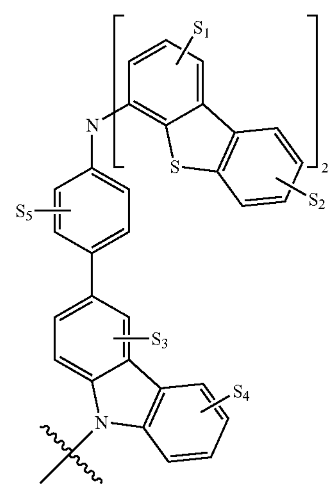
D55



D56



D57



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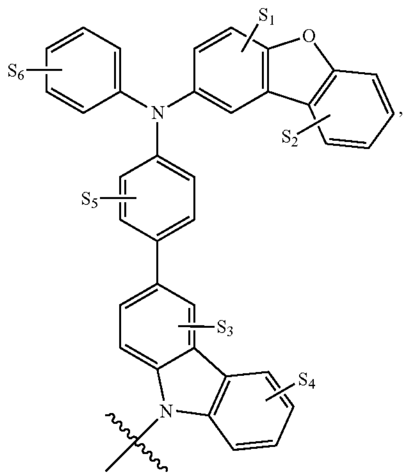
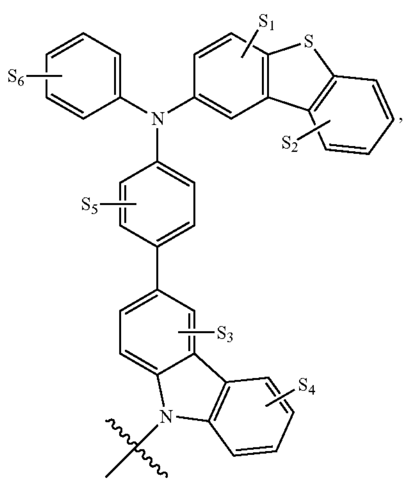
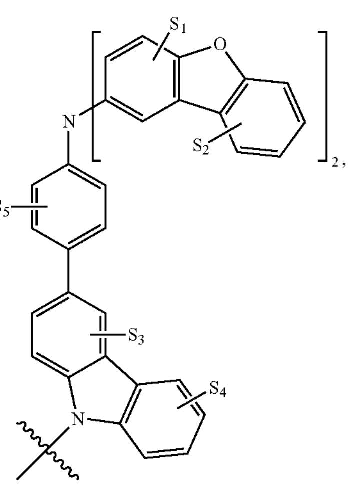
D58



D59



D60



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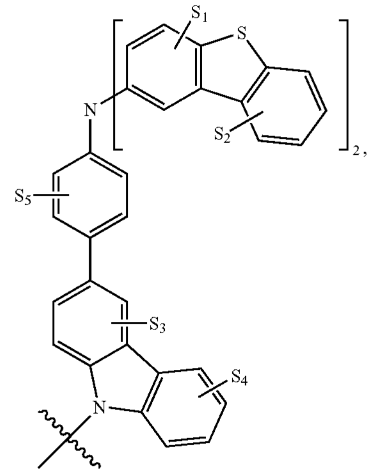
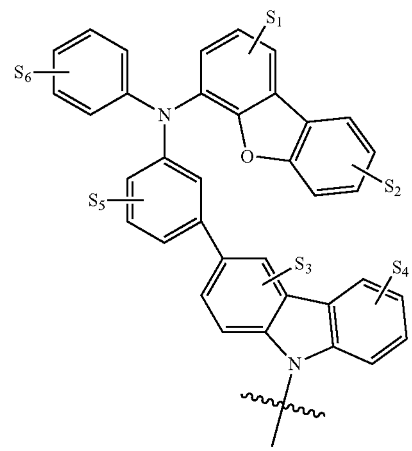
D61



and

D70



wherein S_1 to S_6 represent mono, di, tri, tetra or penta substitutions with hydrogen, deuterium, halide; alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrile, isonitrile, sulfanyl, sulfonyl, phosphino, and combinations thereof.

4. The compound of claim **3**, wherein S_1 to S_6 are H.

5. A first device comprising a first organic light emitting device, the first organic light emitting device comprising:

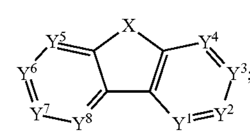
an anode;

a cathode; and

an emissive layer, disposed between the anode and the cathode;

wherein the emissive layer comprises a host material and a first emitting compound having the formula:

Formula 1



wherein each of Y^1 to Y^8 is C—R or N;

wherein at least one of Y^1 to Y^8 is N;

wherein at least one of Y^1 to Y^8 is C—R;

X is O, S, or Se;

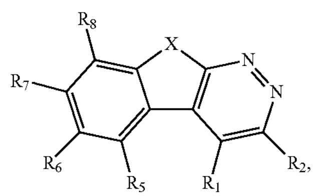
each R is independently selected from the group consisting of hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrile, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof; and

wherein at least one of the R comprises a donor group with at least one electron-donating nitrogen.

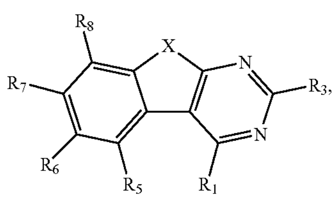
6. The first device of claim **5**, wherein at least two of Y^1 to Y^8 are N.

7. The first device of claim **5**, wherein the first emitting compound is selected from the group consisting of

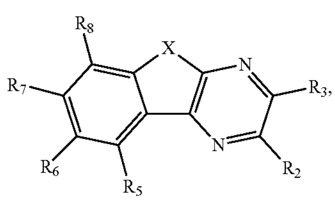
Formula 2



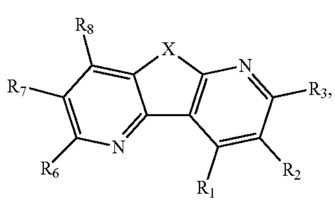
Formula 3



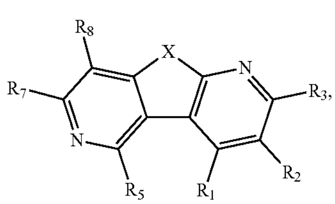
Formula 4



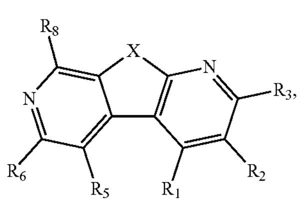
Formula 5



Formula 6



Formula 7



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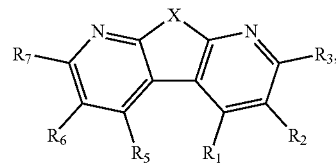
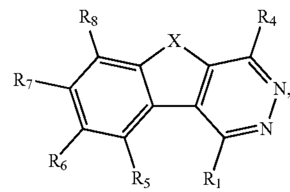
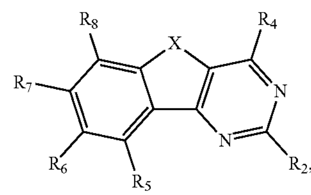
Formula 8



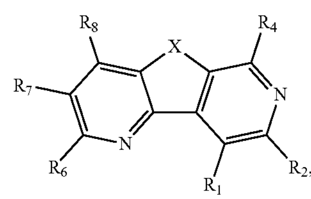
Formula 9



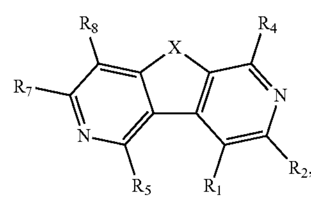
Formula 10



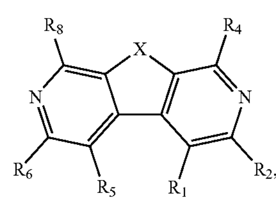
Formula 11



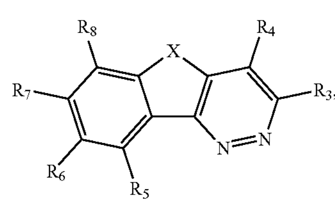
Formula 12



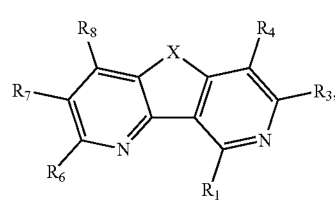
Formula 13



Formula 14



Formula 15



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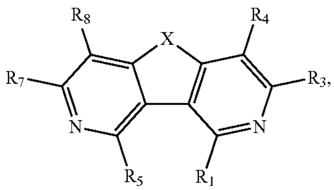
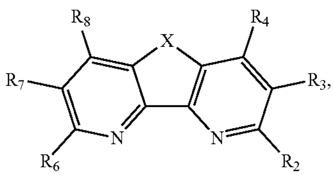
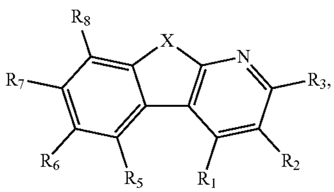
Formula 16



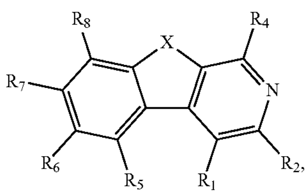
Formula 17



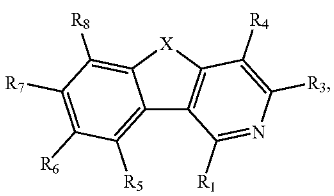
Formula 18



Formula 19

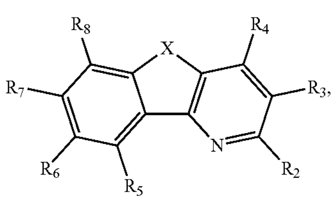


Formula 20



and

Formula 21



wherein R_1-R_8 is independently hydrogen, deuterium, halide, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrile, isonitrile, sulfanyl, sulfonyl, phosphino, and combinations thereof;

at least one of R_1 to R_8 is $(L\text{—})_m\text{—}(\text{Donor})_n$;

wherein L is a linker,

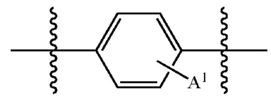
in is 1 or 0,

n≥1; and

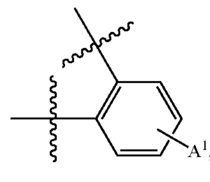
wherein Donor is an electron donating group containing at least one electron-donating nitrogen and Donors can be different when n>1.

8. The first device of claim **7**, wherein the linker L is selected from the group consisting of

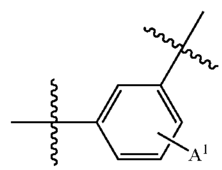
L1



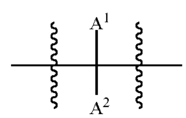
L2



L3

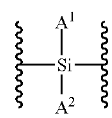


L4



, and

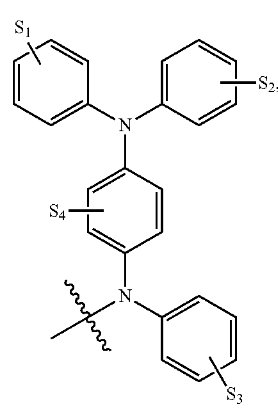
L5



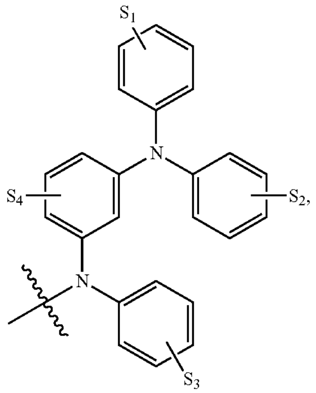
wherein A^1 to A^2 represent mono, di, tri or tetra substitutions with hydrogen, deuterium, halide, cycloalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof.

9. The first device of claim **7**, wherein the Donor is selected from the group consisting of:

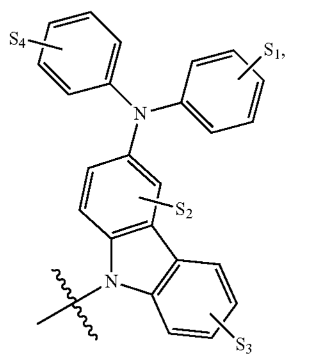
D1



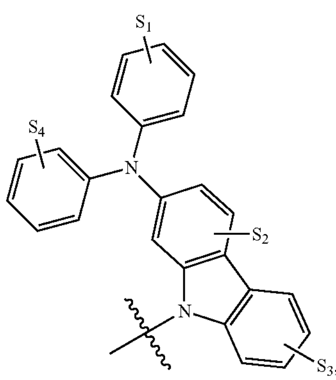
D2



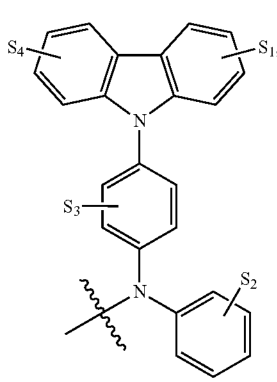
D3



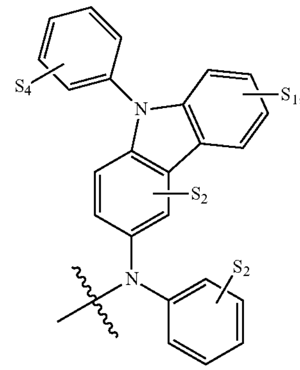
D4



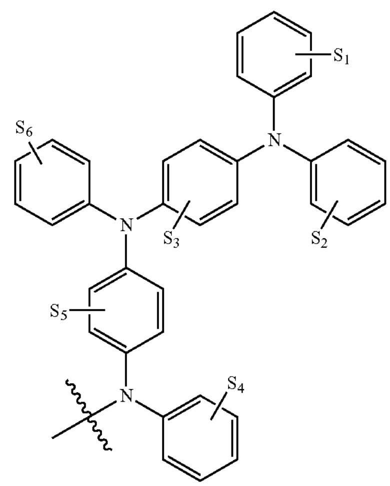
D5



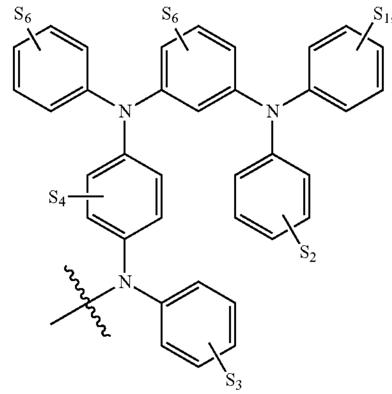
D6



D7



D8



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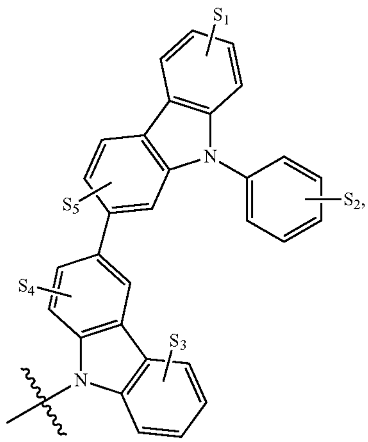
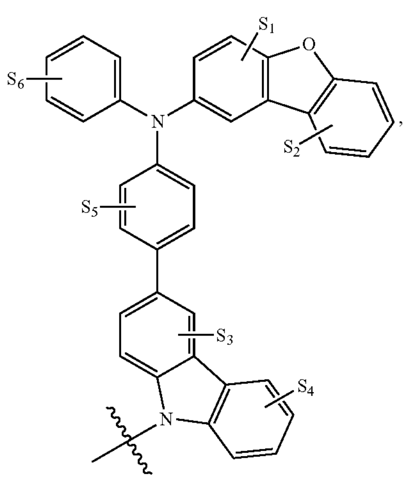
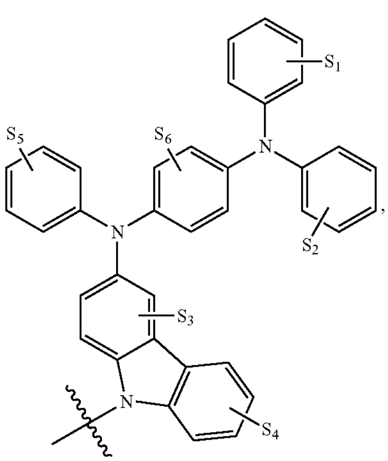
D9



D10



D11



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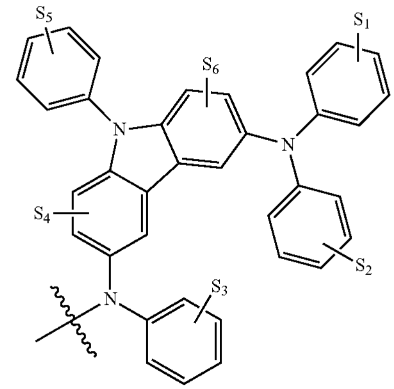
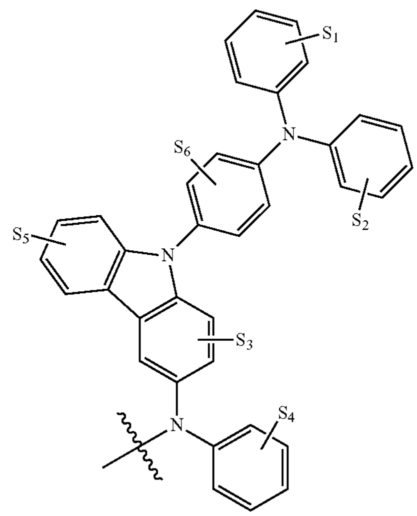
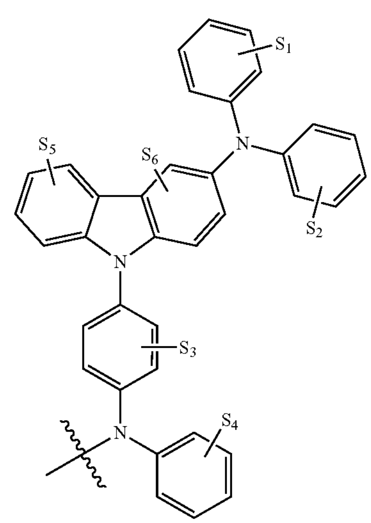
D12



D13



D14



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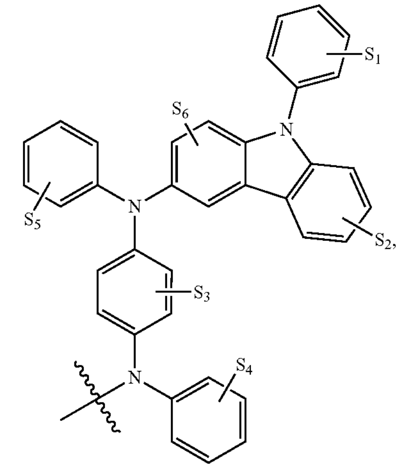
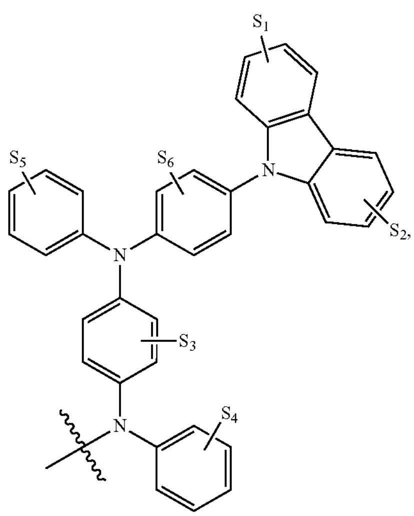
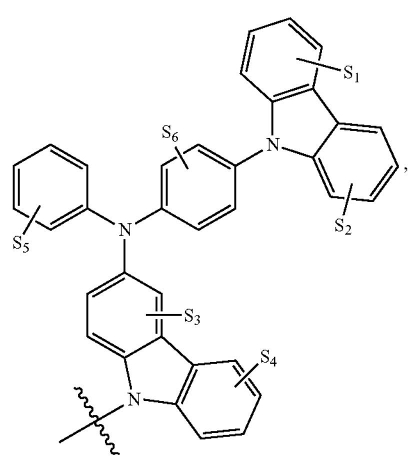
D15



D16



D17



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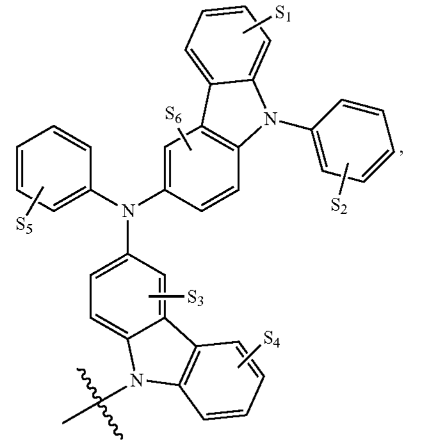
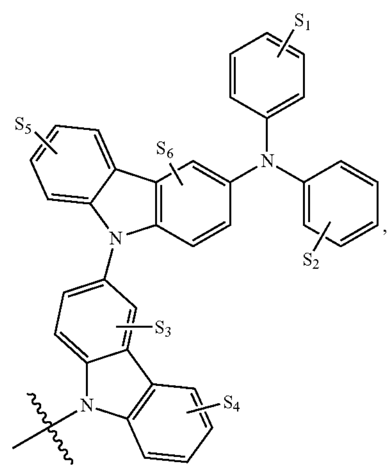
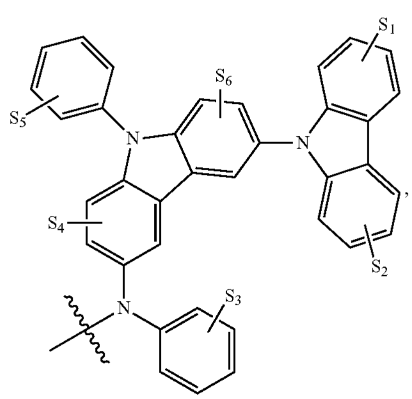
D18



D19



D20



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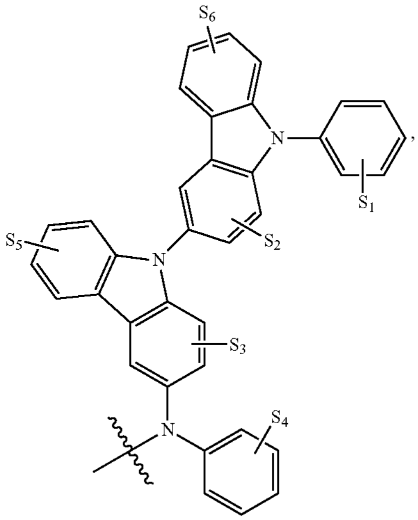
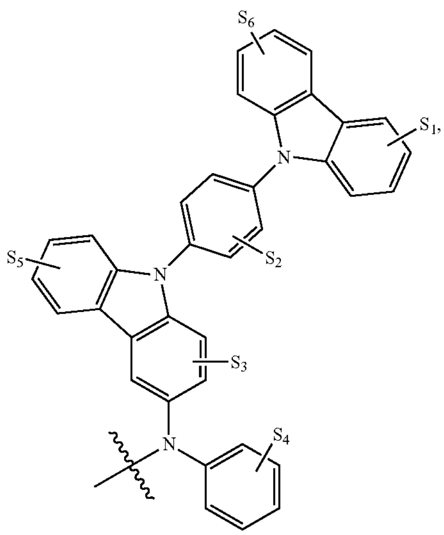
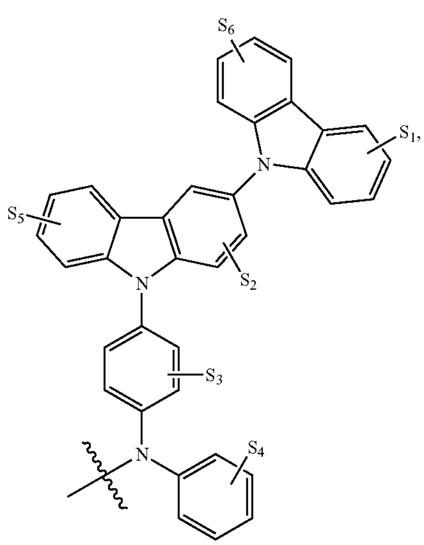
D21



D22



D23



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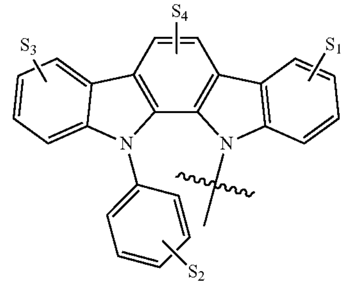
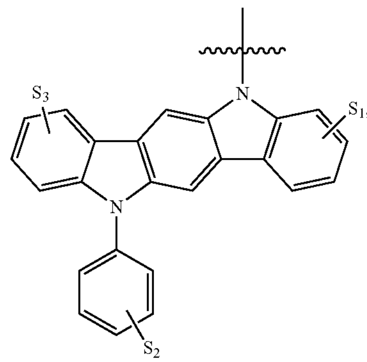
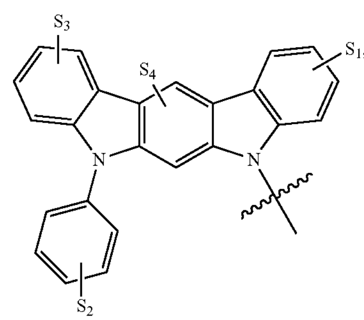
D24



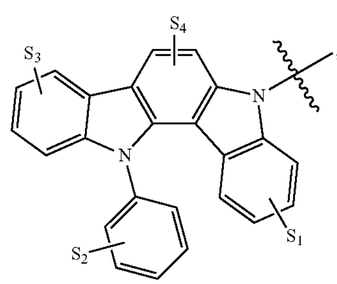
D25



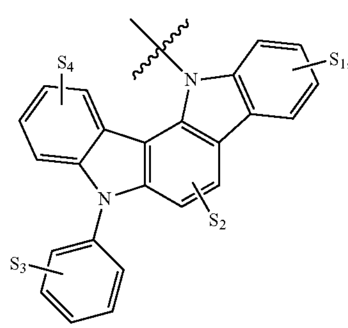
D26



D27



D28



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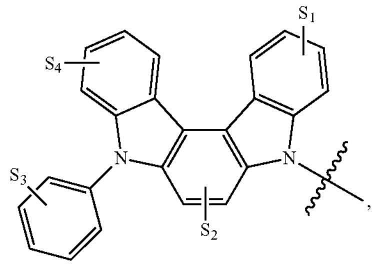
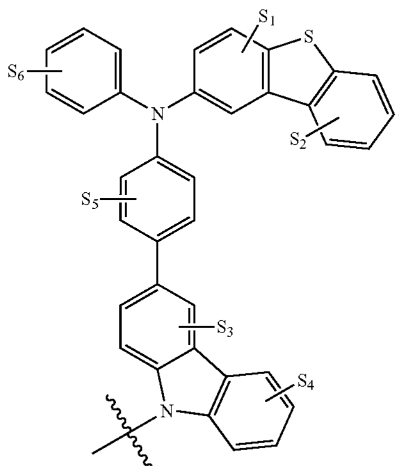
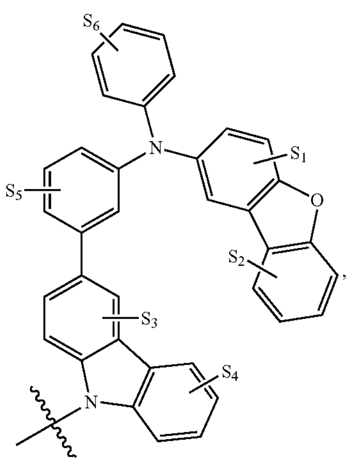
D29



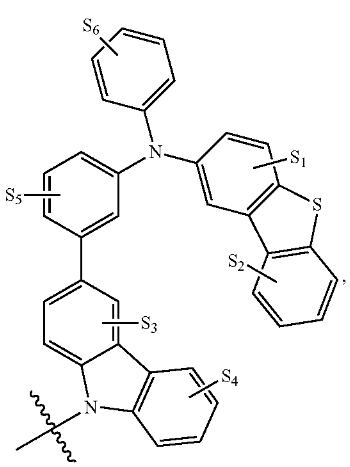
D30



D31



D32



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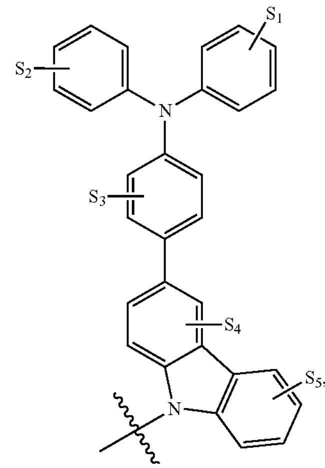
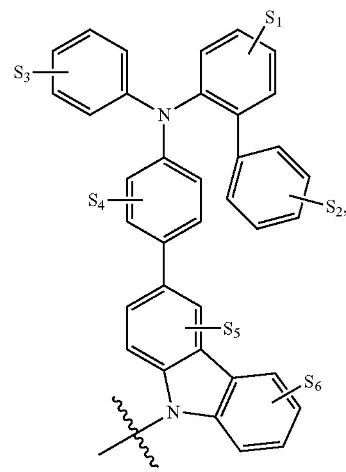
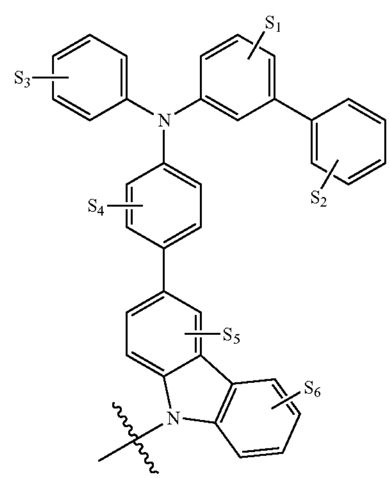
D33



D34



D35



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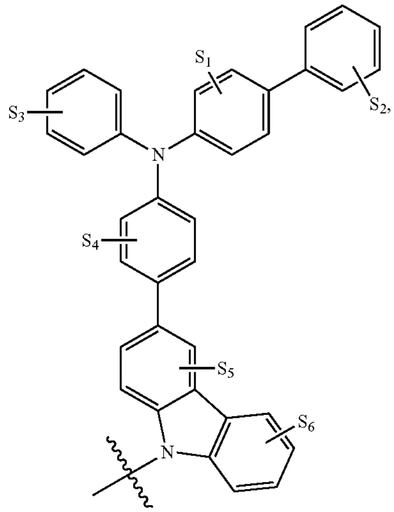
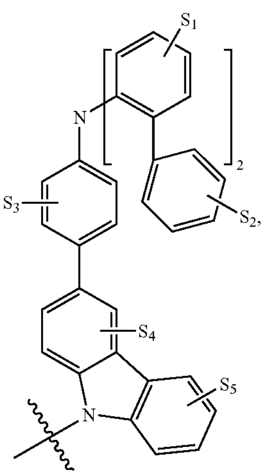
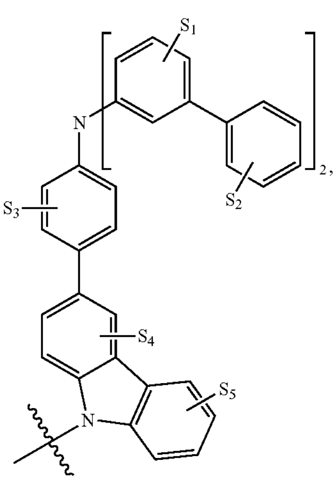
D36



D37



D38



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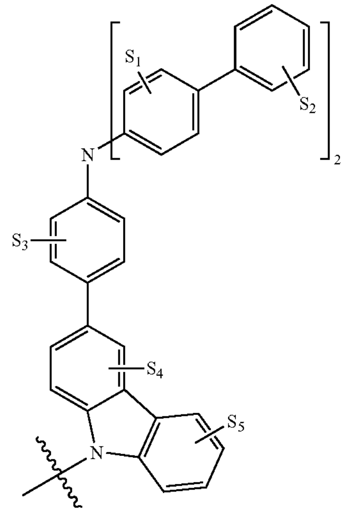

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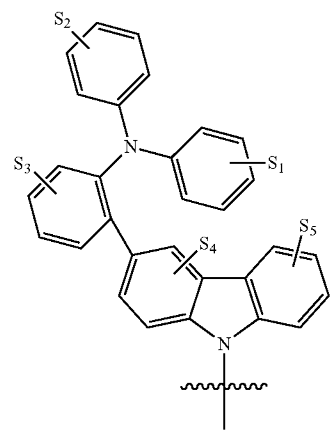

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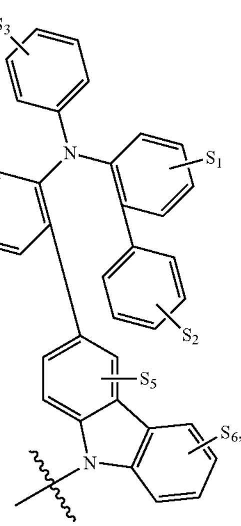

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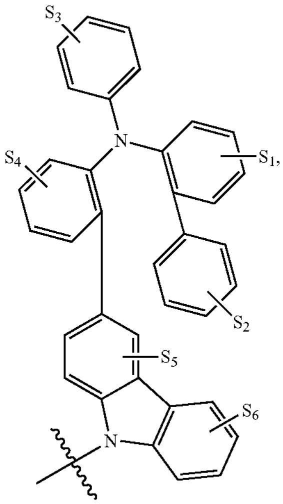

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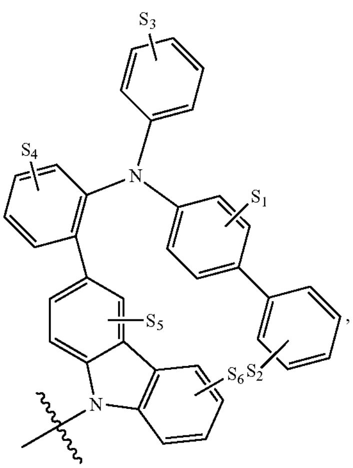

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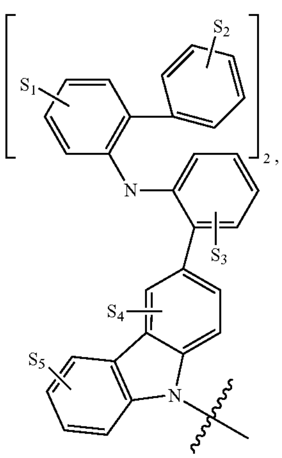

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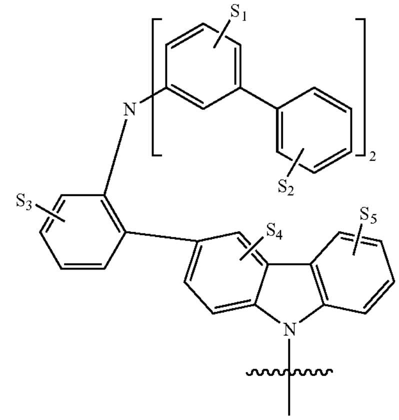

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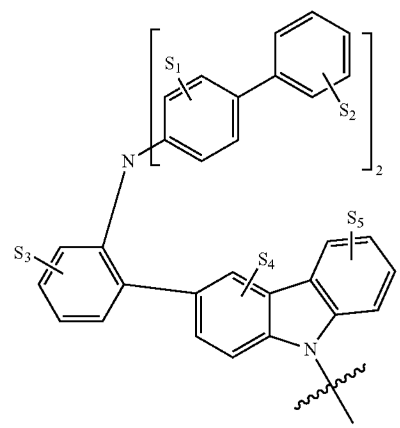

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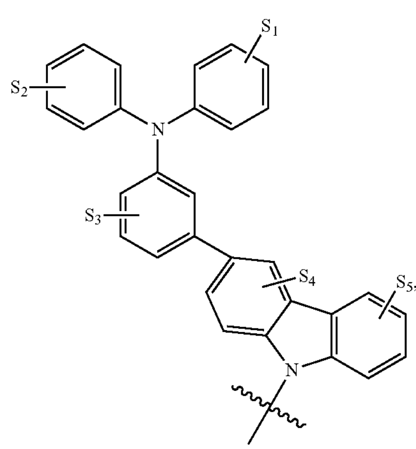

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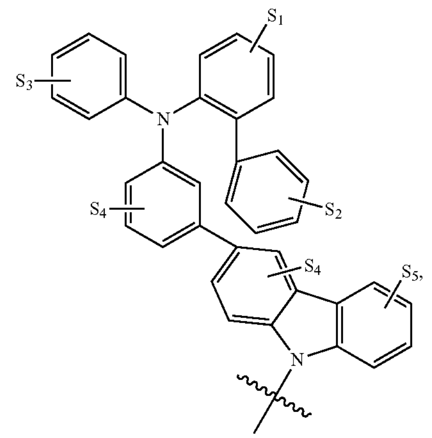

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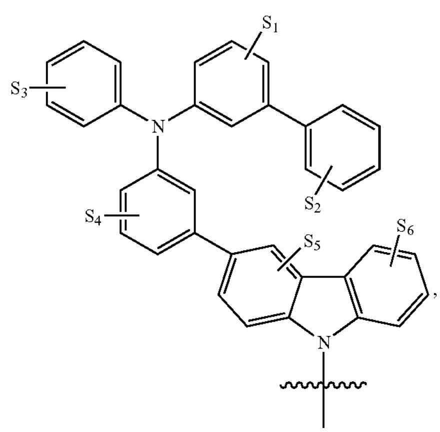

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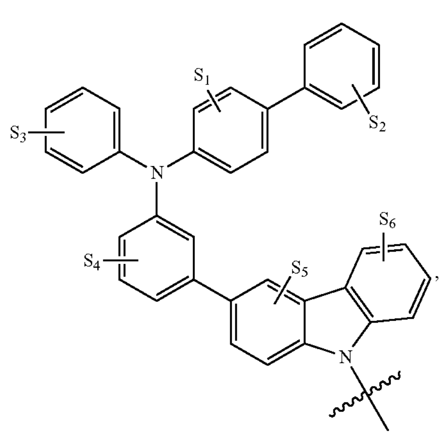

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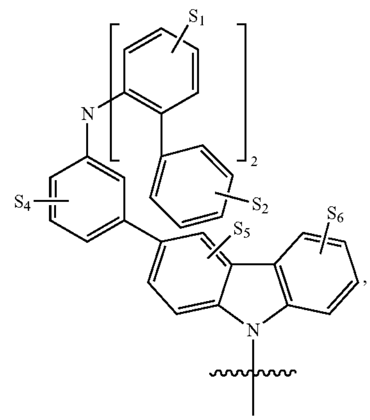

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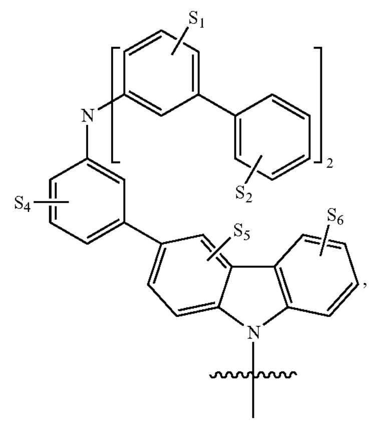

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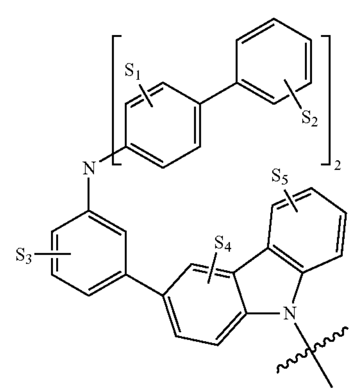

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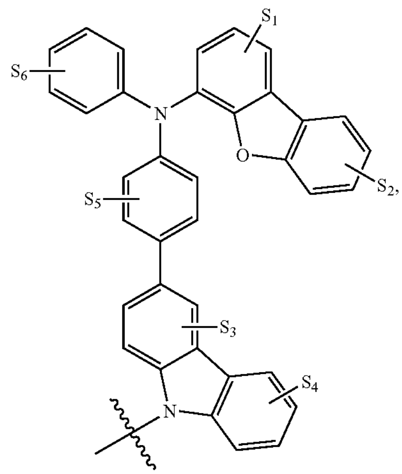

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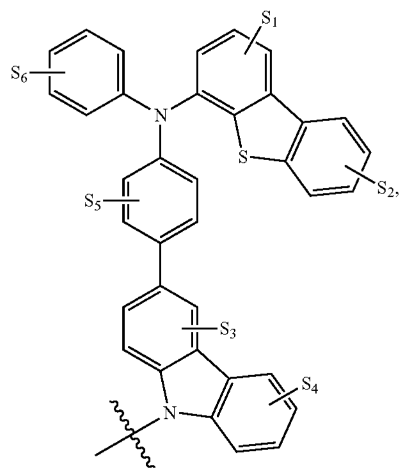

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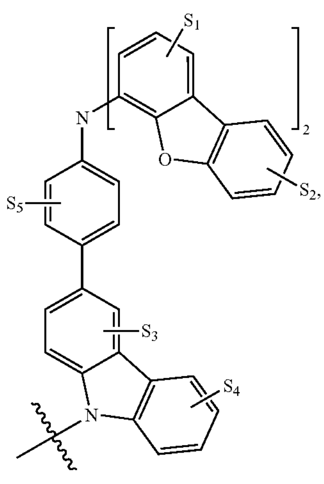

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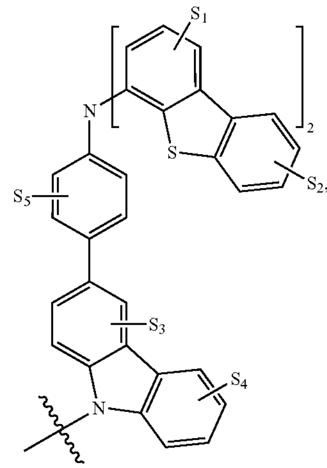

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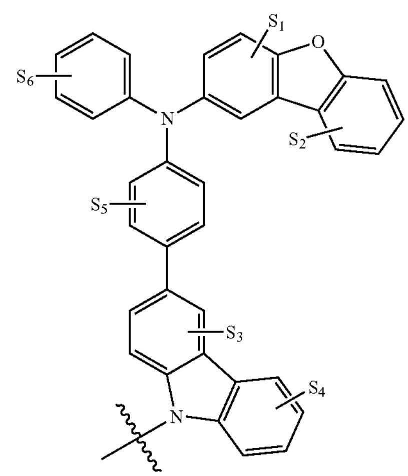

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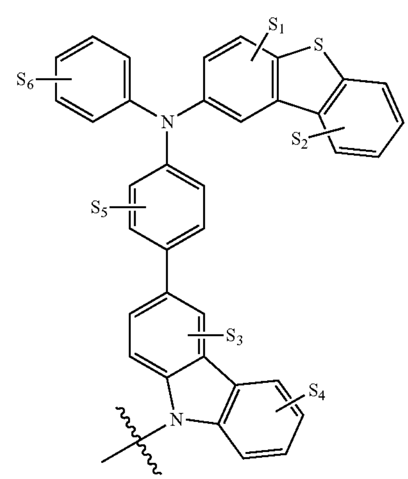

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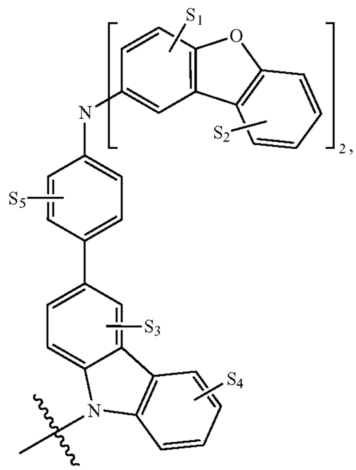

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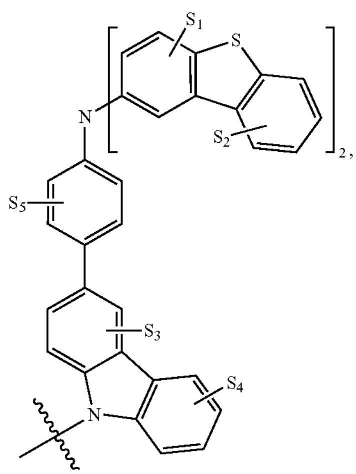

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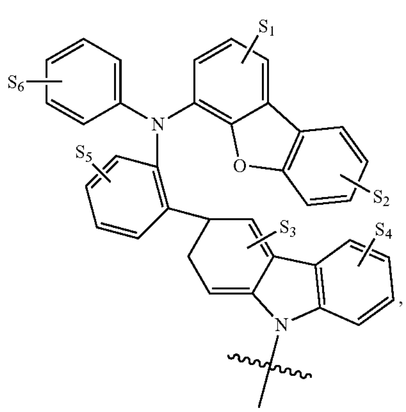

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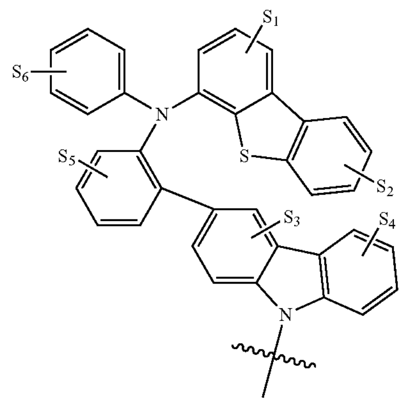

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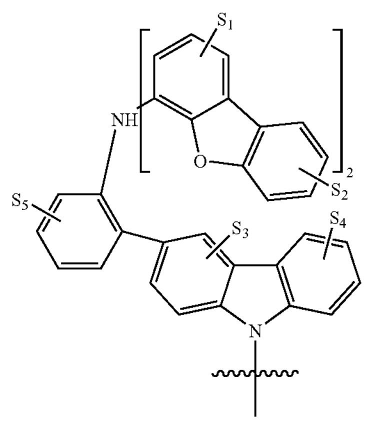

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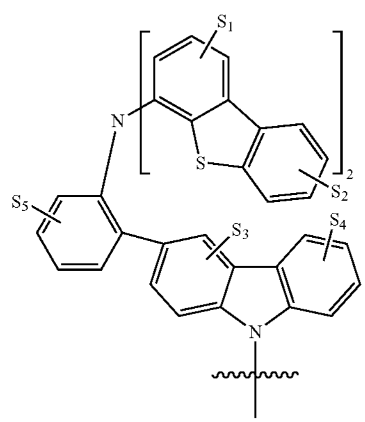

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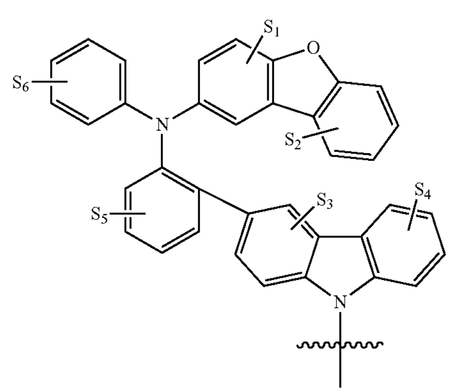

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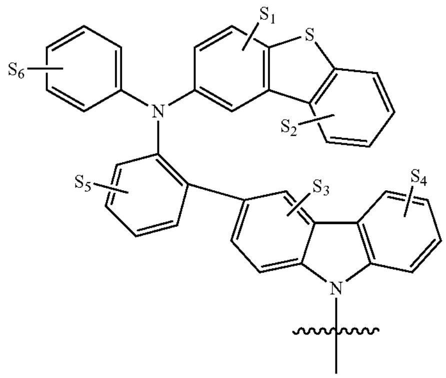

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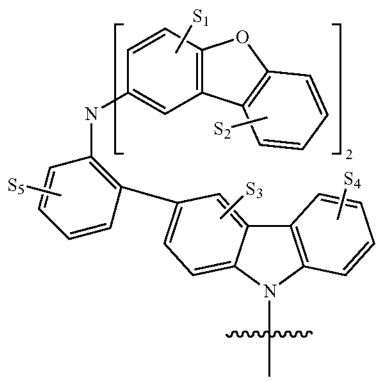

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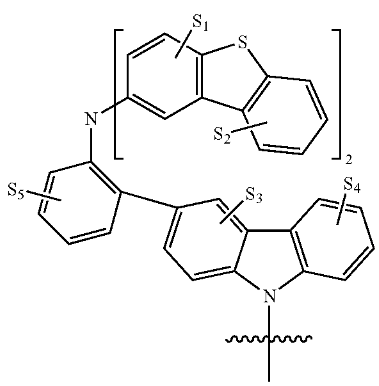

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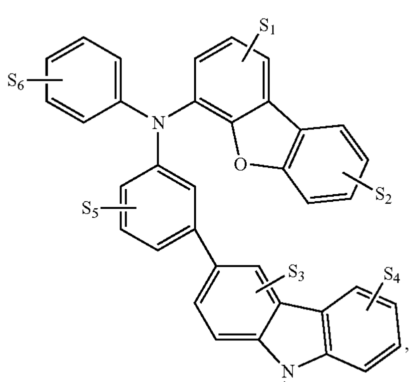

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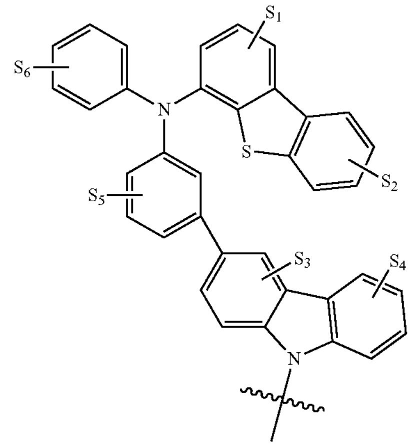

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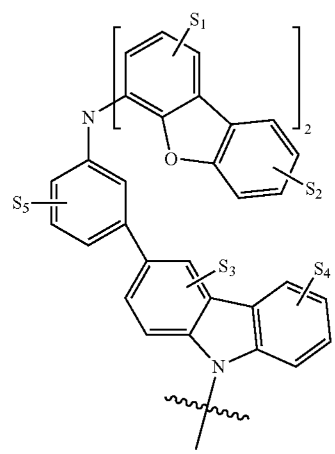

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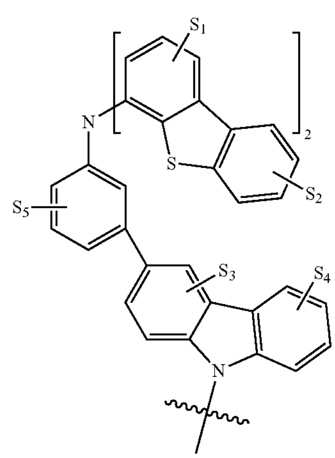

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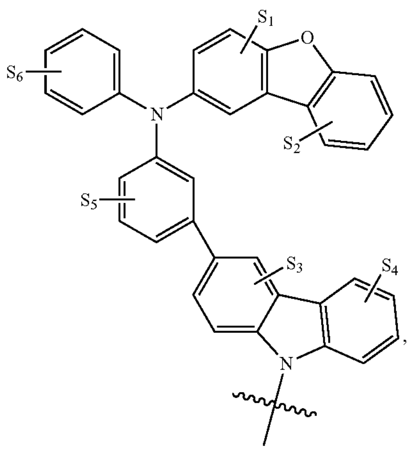

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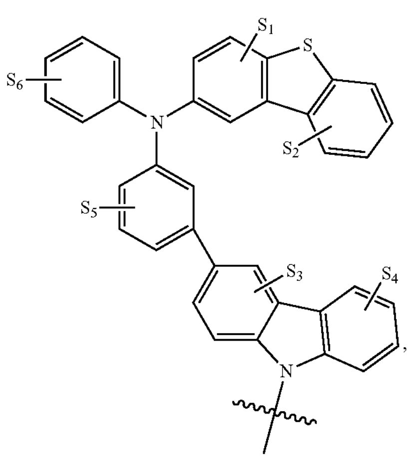

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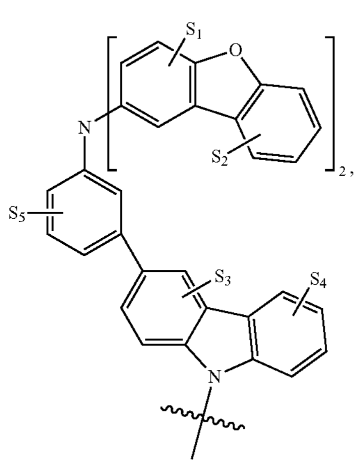

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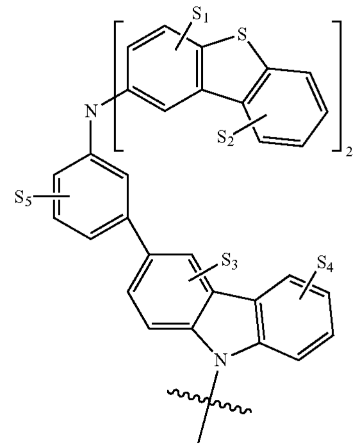

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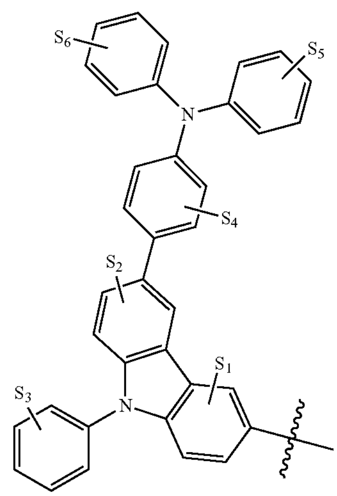

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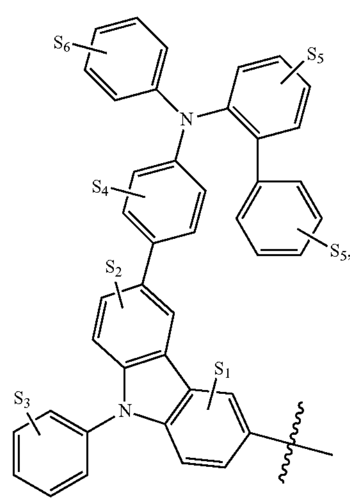

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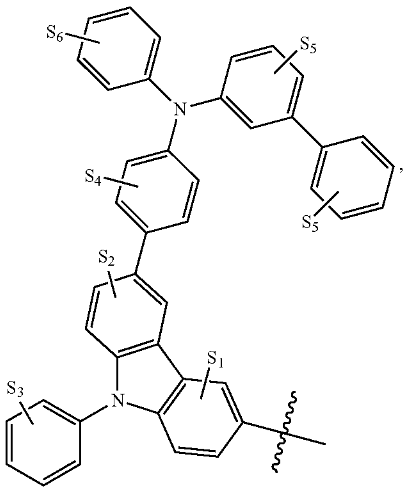

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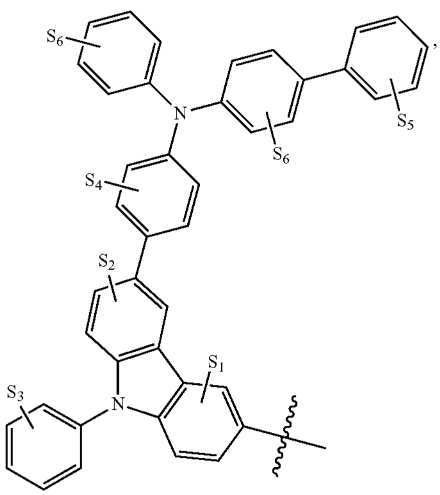

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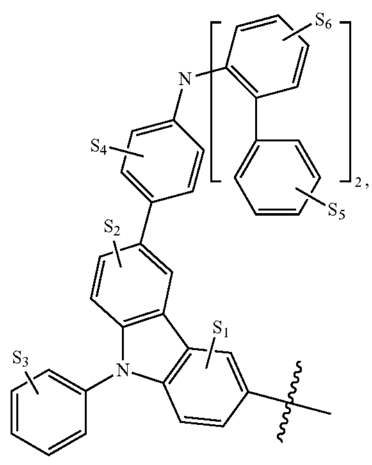

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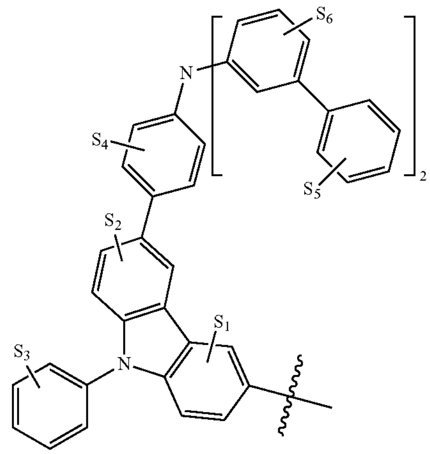

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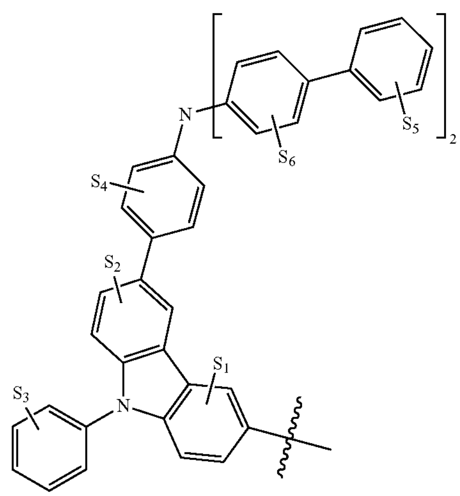

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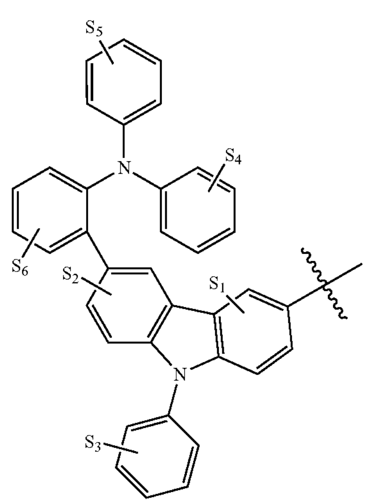

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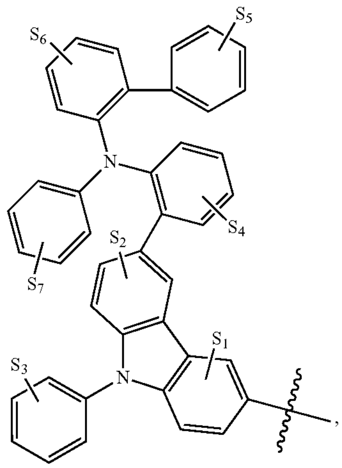

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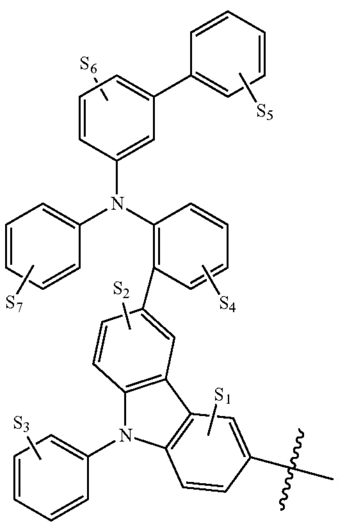

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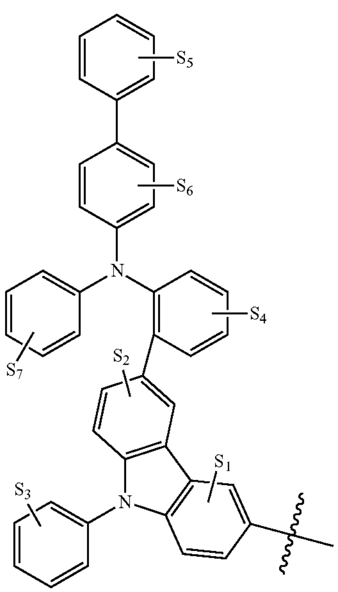

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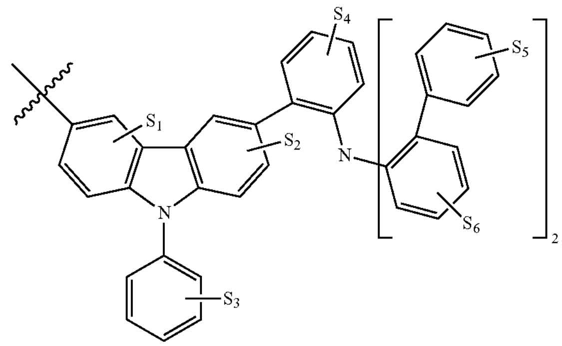

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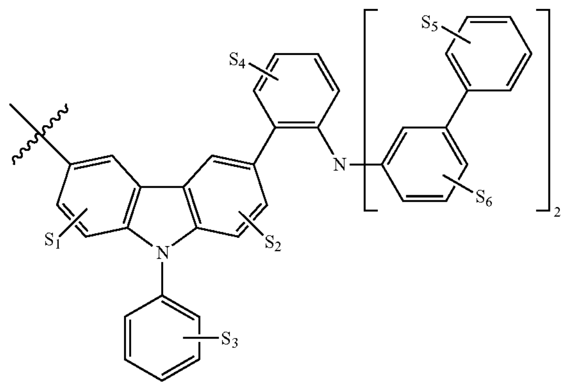

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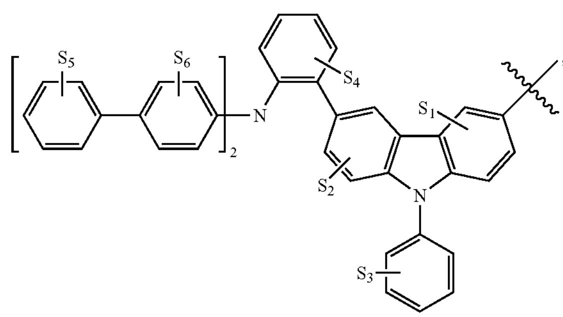

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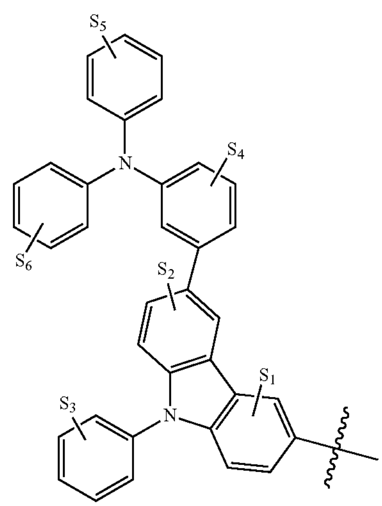

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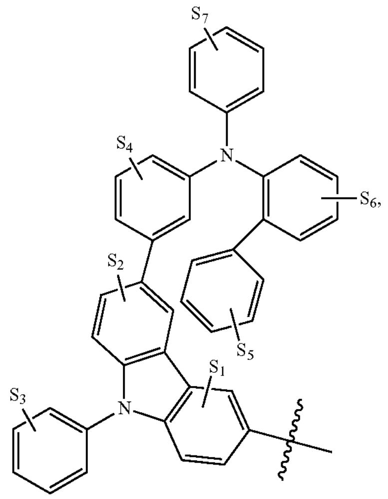

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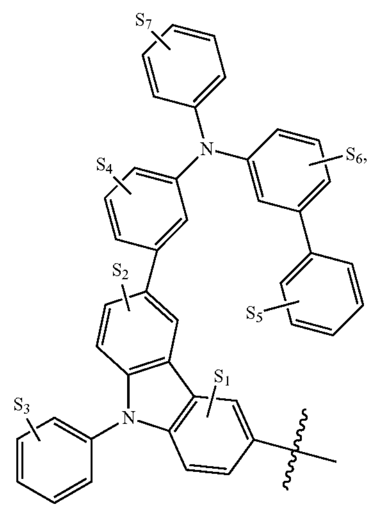

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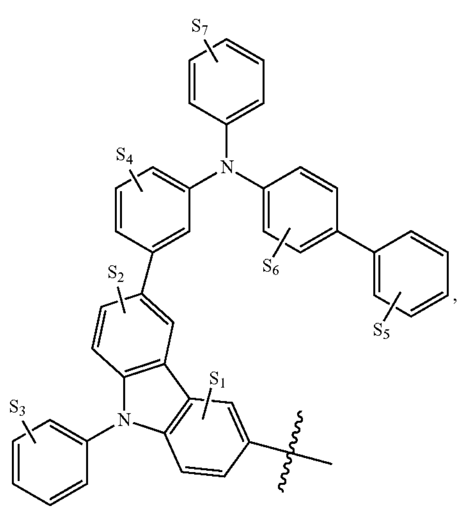

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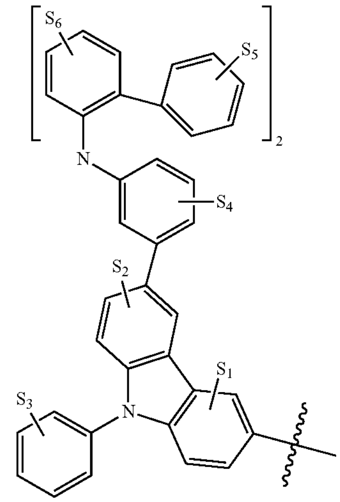

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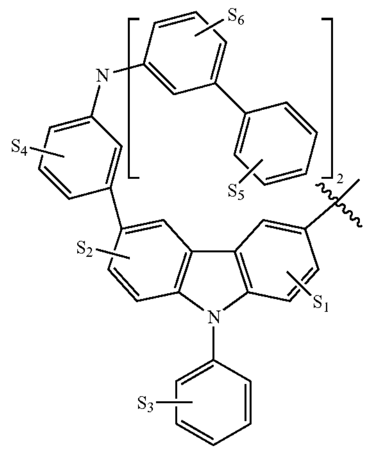

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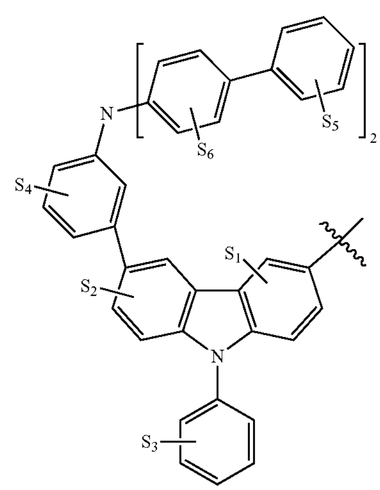

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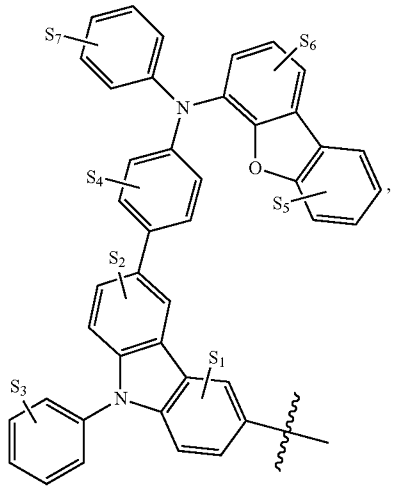

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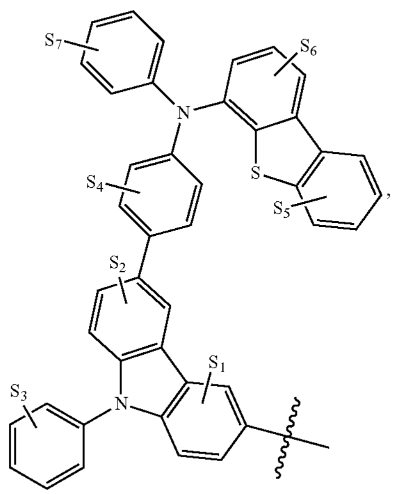

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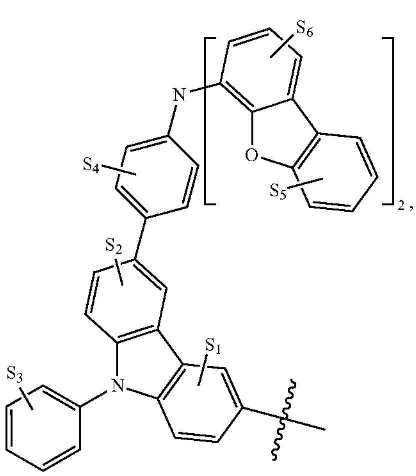

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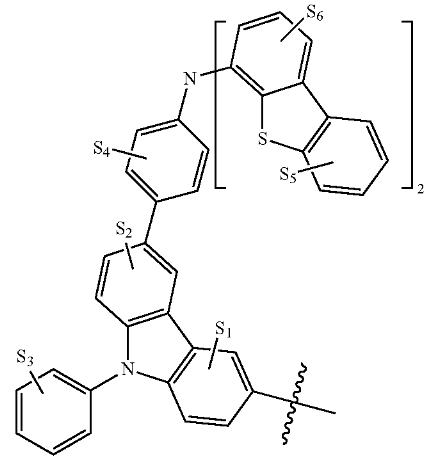

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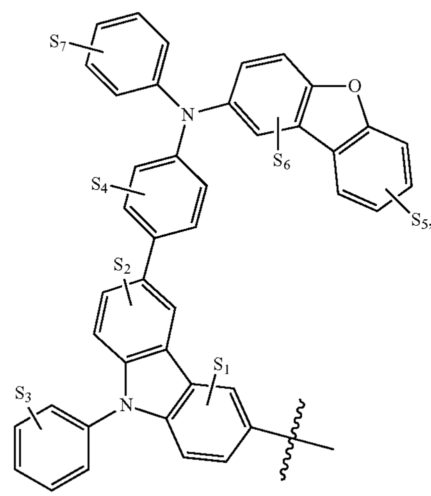

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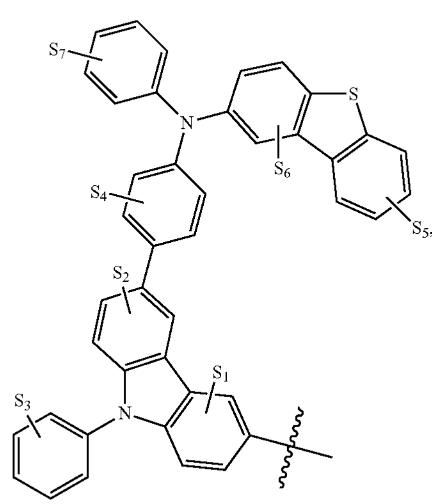

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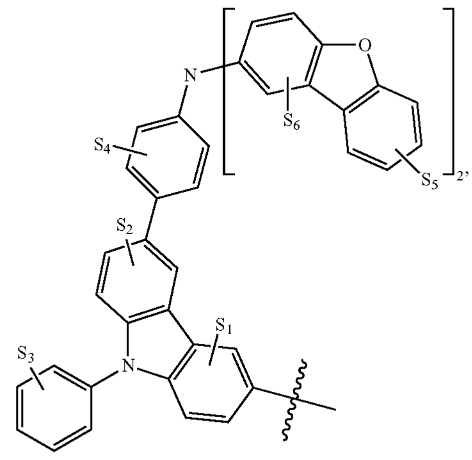

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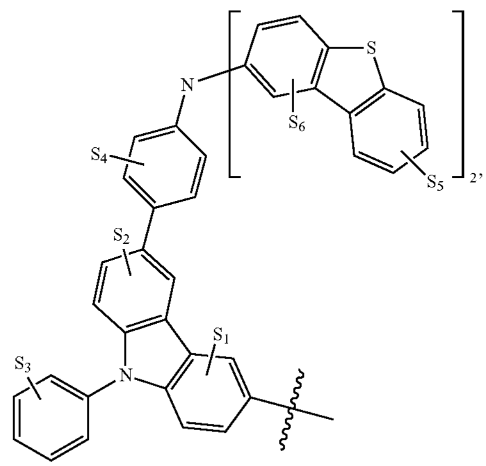

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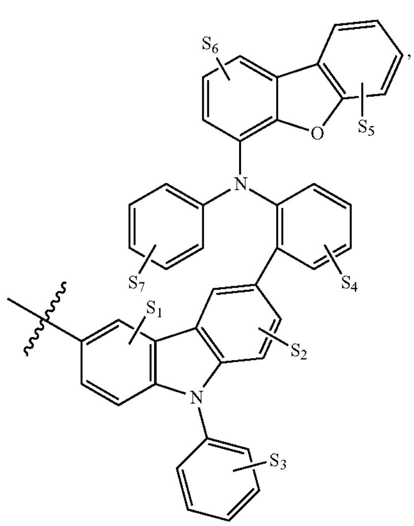

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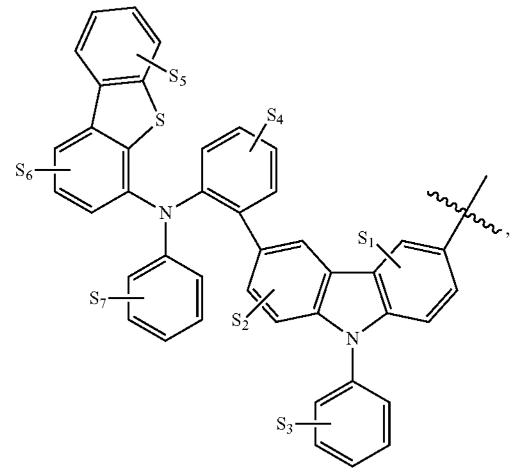

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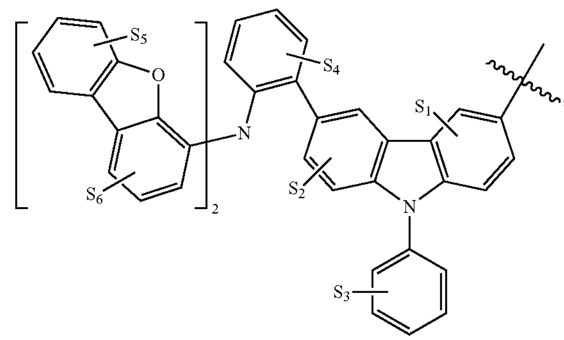

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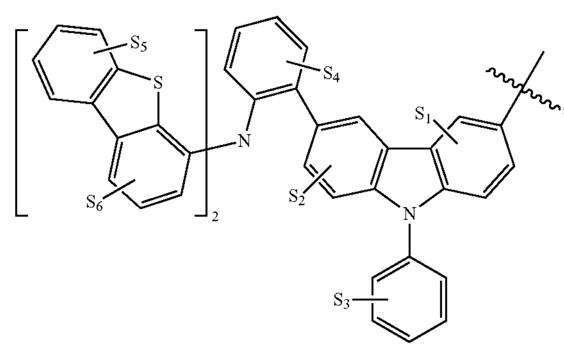

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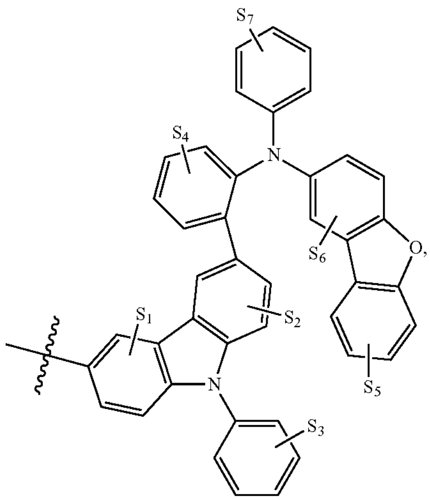

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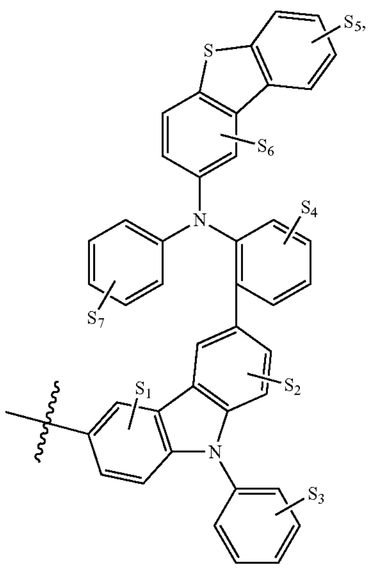
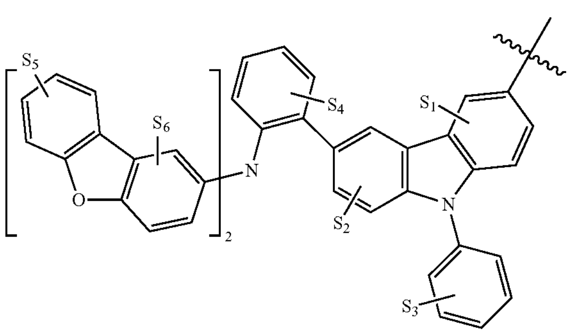
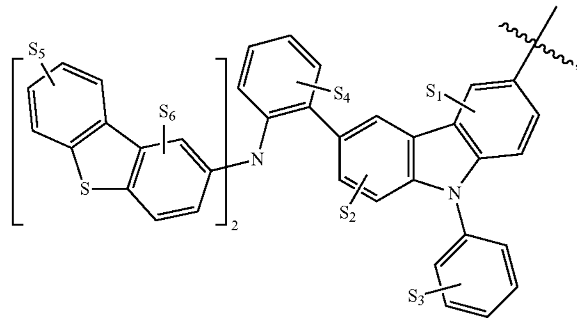


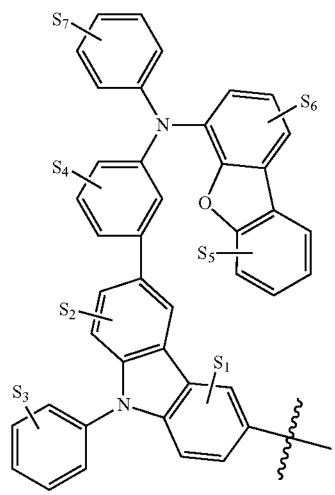
D113



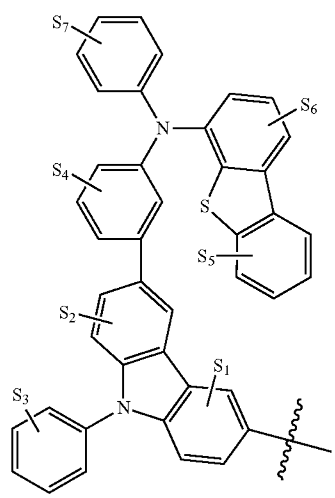
D114



D115



D116



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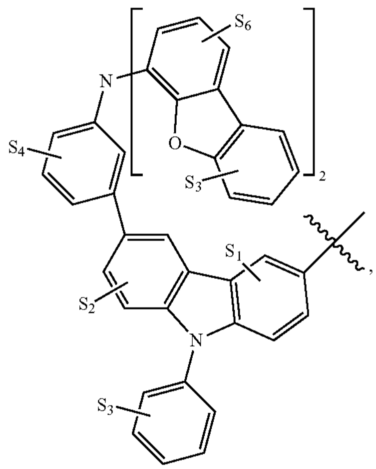
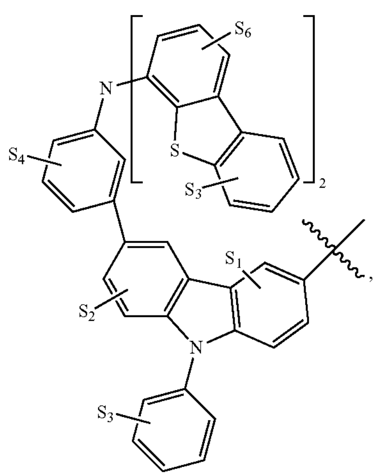
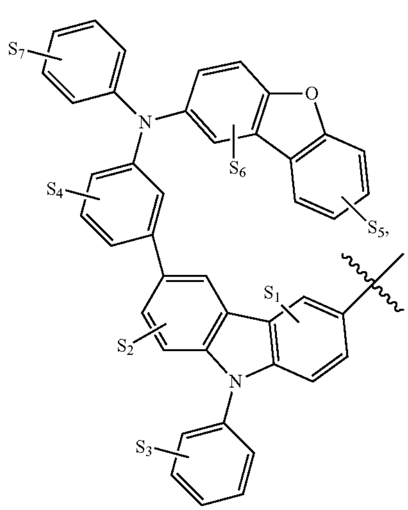
D117



D118



D119



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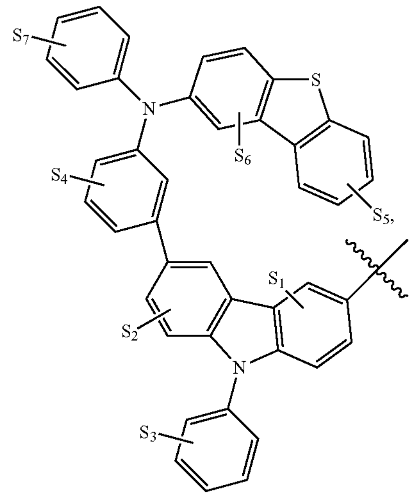
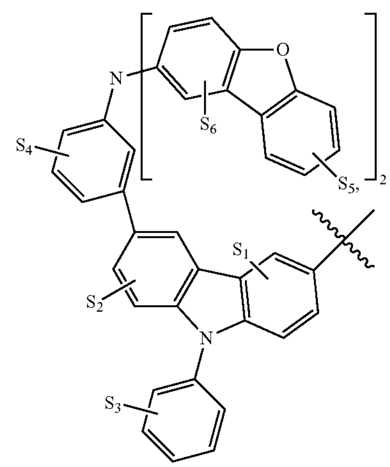
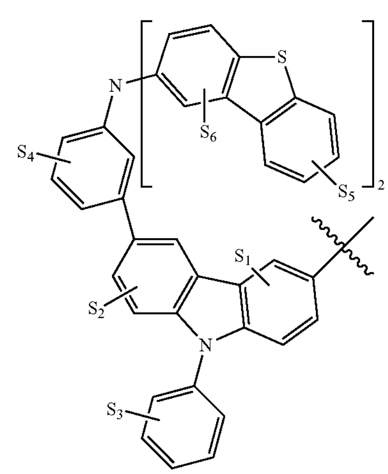
D120



D121



D122



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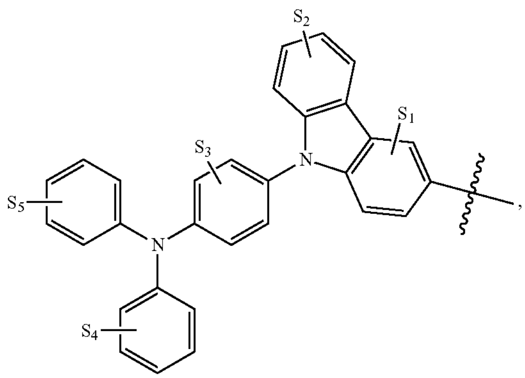
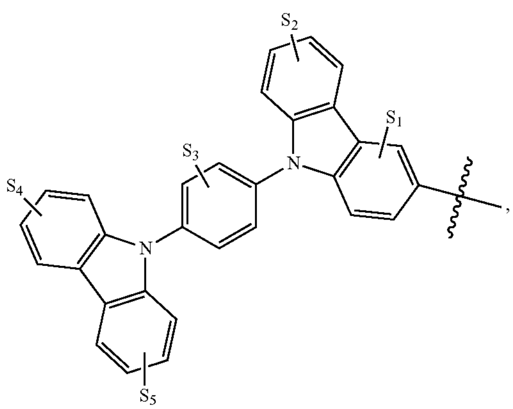
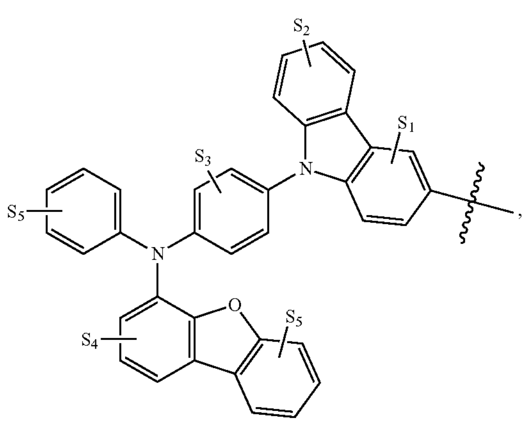
D123



D124



D125



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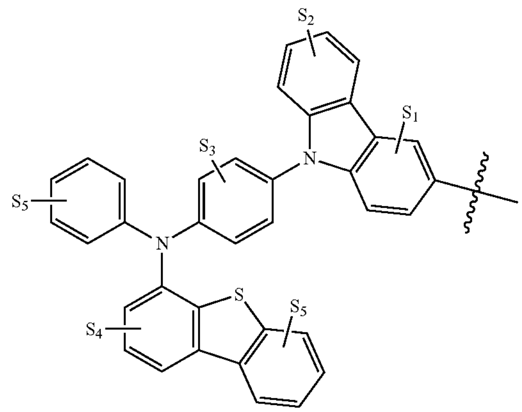
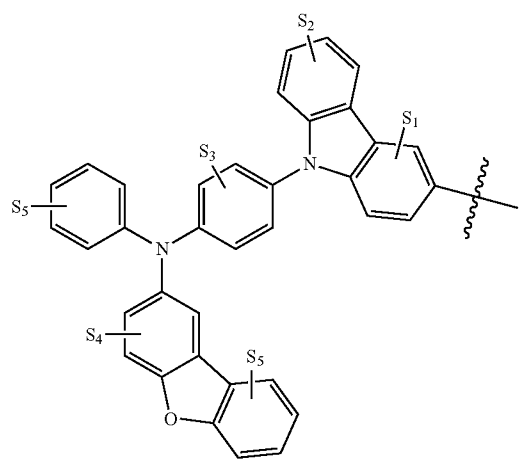
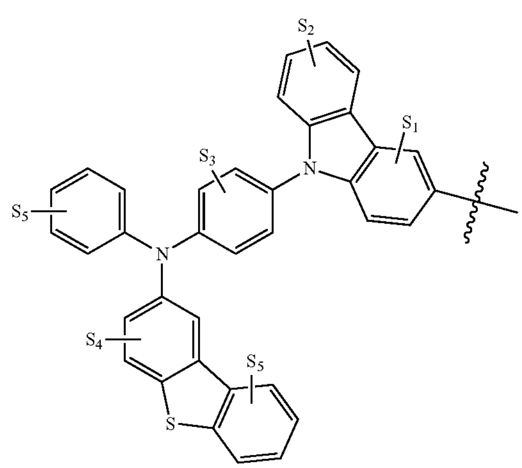
D126



D127



D128



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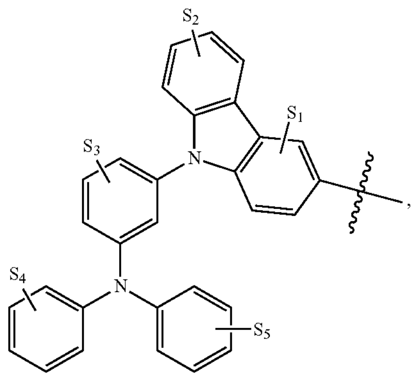
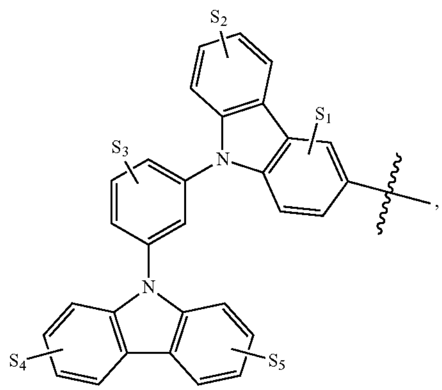
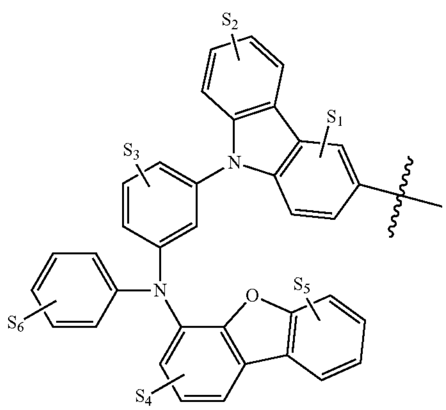
D129



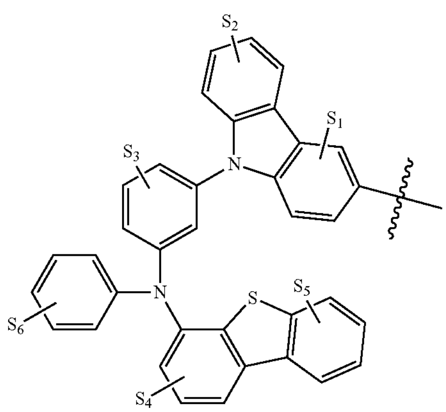
D130



D131



D132



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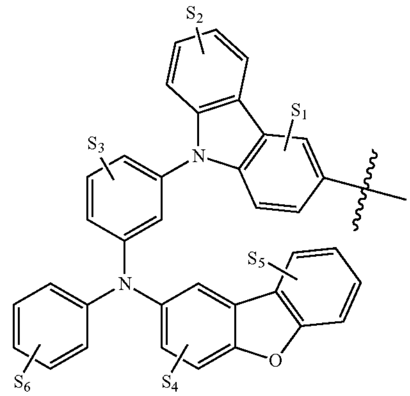
D133



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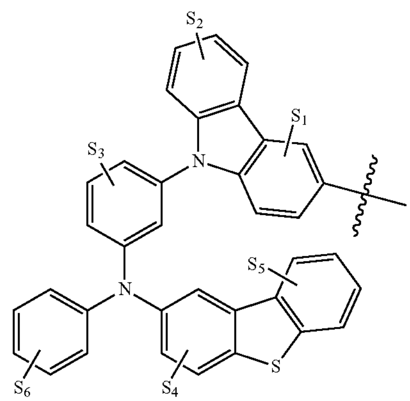
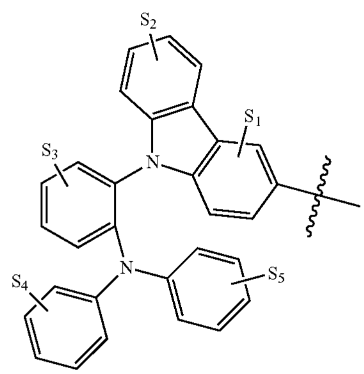
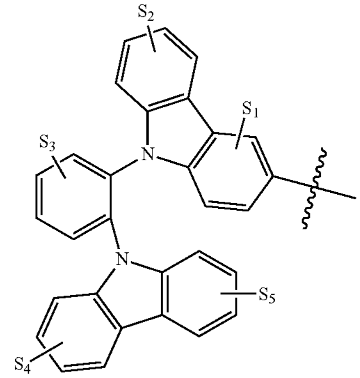


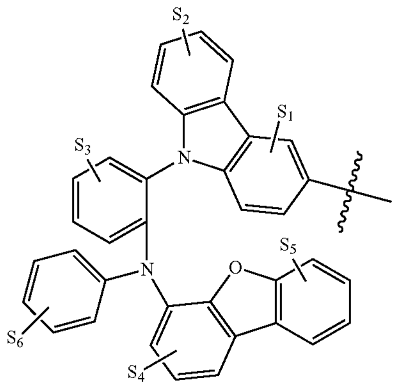
D135



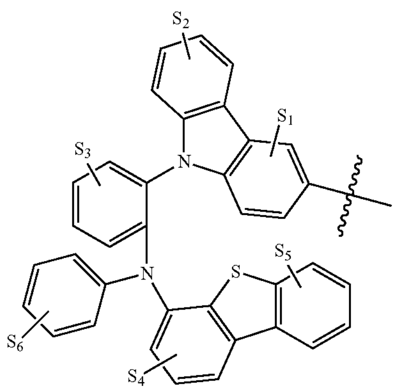
D136



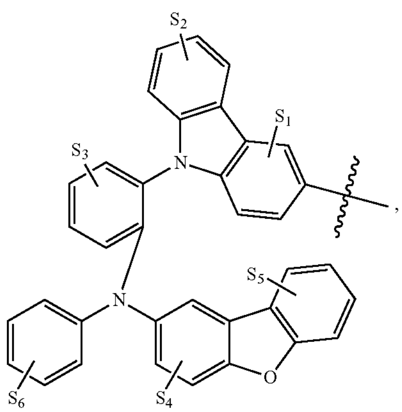
D137



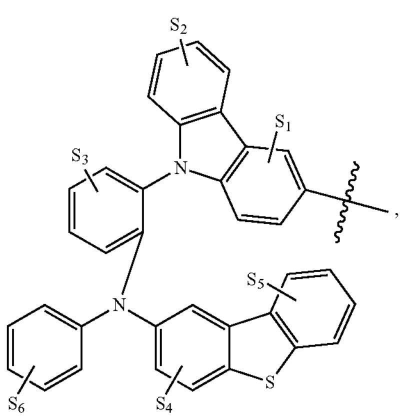
D138



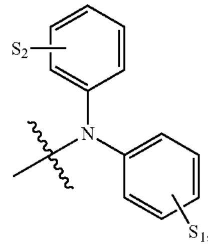
D139



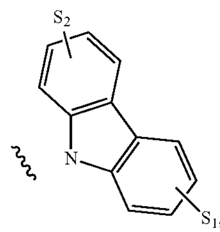
D140



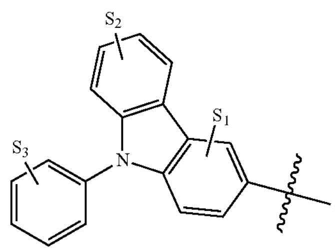
D141



D142

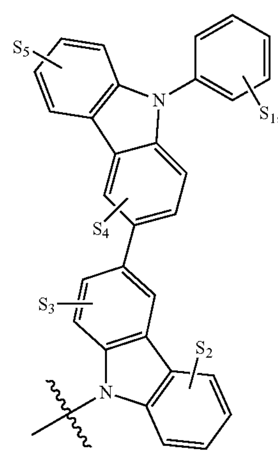


D143



and

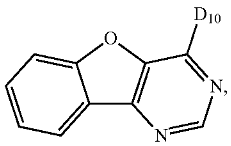
D144



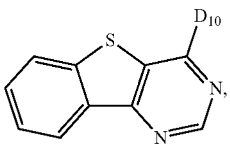
wherein S_1 to S_7 represent mono, di, tri, tetra or penta substitutions with hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrile, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof.

10. The first device of claim 5, wherein the first emitting compound is selected from the group consisting of:

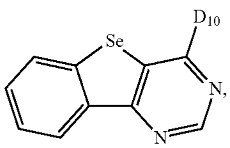
Compound O-10-10



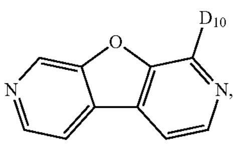
Compound S-10-10



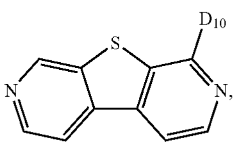
Compound Se-10-10



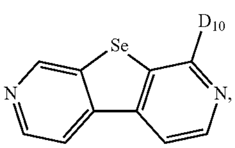
Compound O-13-10



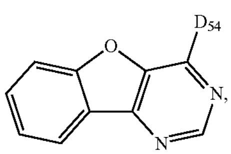
Compound S-13-10



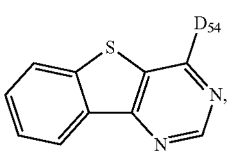
Compound Se-13-10



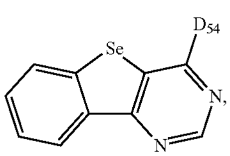
Compound O-10-54



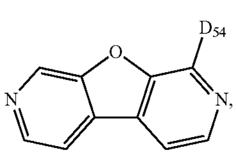
Compound S-10-54



Compound Se-10-54



Compound O-13-54



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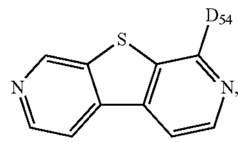
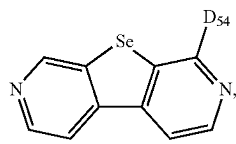
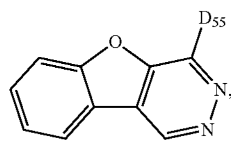
Compound S-13-54



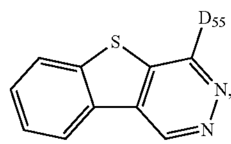
Compound Se-13-54



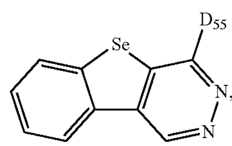
Compound O-10-55



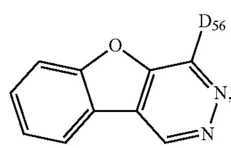
Compound S-10-55



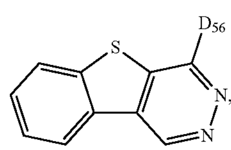
Compound Se-10-55



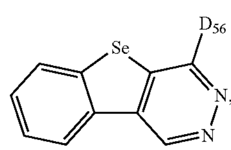
Compound O-10-56



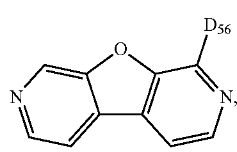
Compound S-10-56



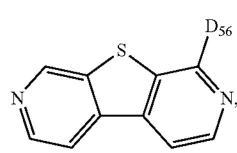
Compound Se-10-56



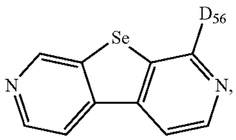
Compound O-13-56



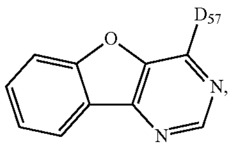
Compound S-13-56



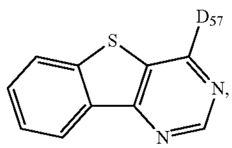
Compound Se-13-56



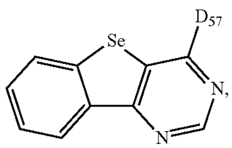
Compound O-10-57



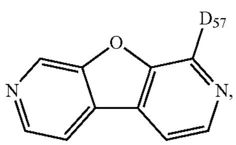
Compound S-10-57



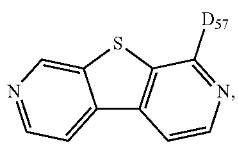
Compound Se-10-57



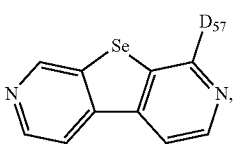
Compound O-13-57



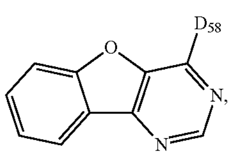
Compound S-13-57



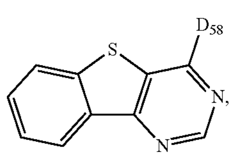
Compound Se-13-57



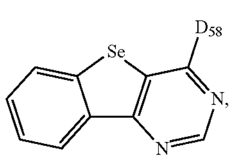
Compound O-10-58



Compound S-10-58



Compound Se-10-58



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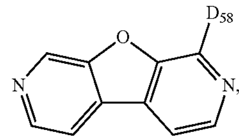
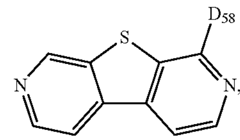


Compound S-13-58



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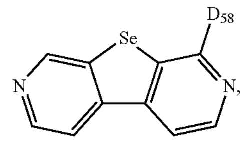

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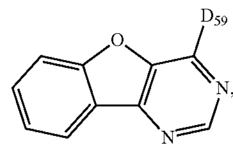
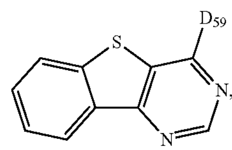
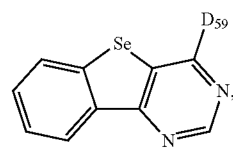


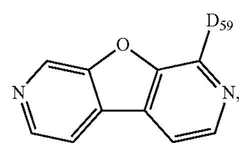
Compound S-10-59



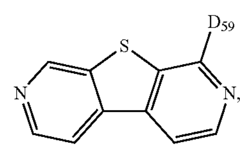
Compound Se-10-59



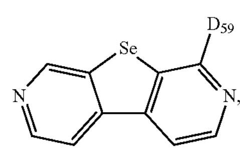
Compound O-13-59



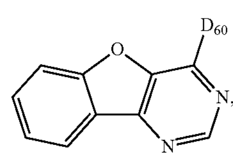
Compound S-13-59



Compound Se-13-59



Compound O-10-60



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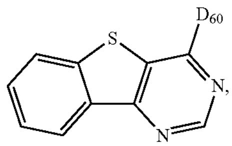
Compound S-10-60



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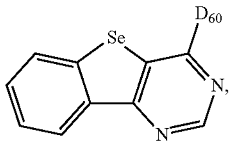
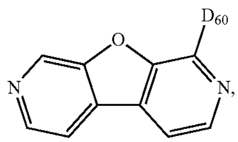
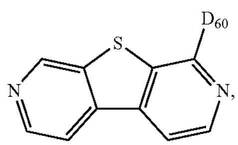


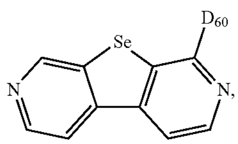
Compound O-13-60



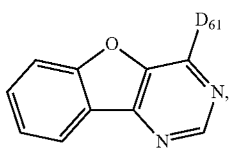
Compound S-13-60



Compound Se-13-60



Compound O-10-61



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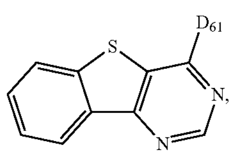
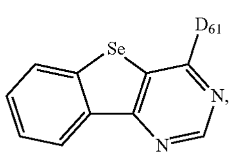
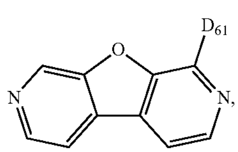


Compound Se-10-61



Compound O-13-61



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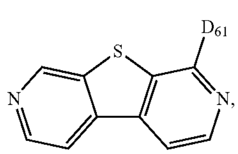

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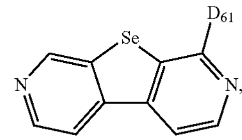
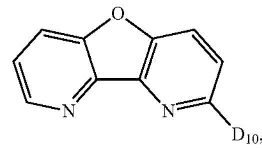
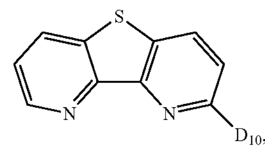
Compound Se-13-61



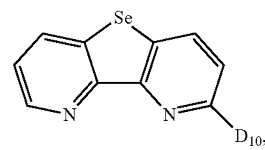
Compound O-17-10



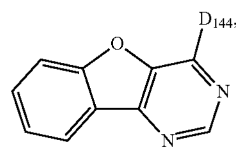
Compound S-17-10



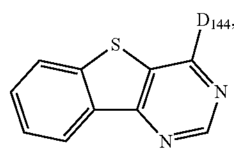
Compound Se-17-10



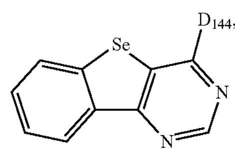
Compound O-10-144



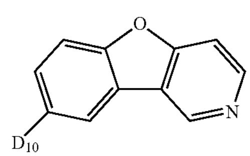
Compound S-10-144



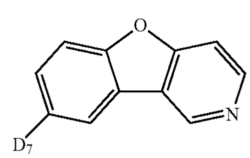
Compound Se-10-144



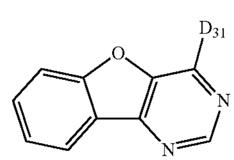
Compound O-20-10



Compound O-20-7



Compound O-10-31



and

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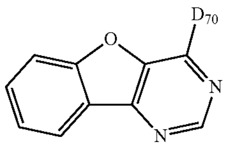
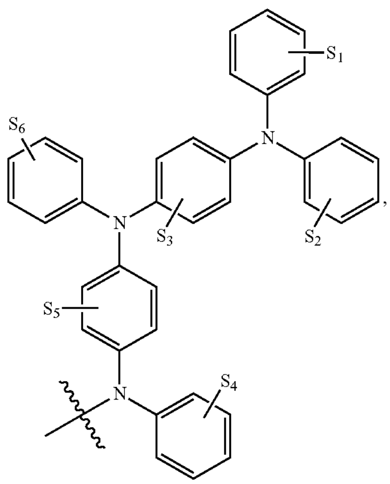
Compound O-10-70

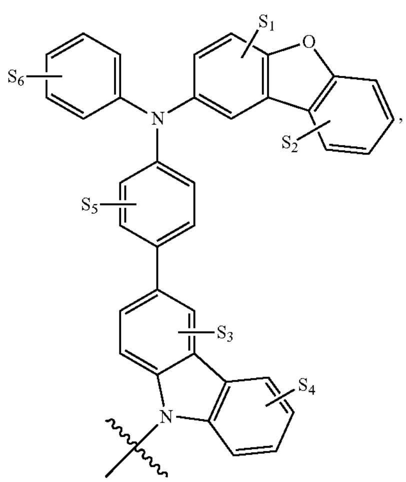


wherein D7, D10, D31, D54, D55, D56, D57, D58, D59, D60, D61, D70 and D144 are

D7



D10



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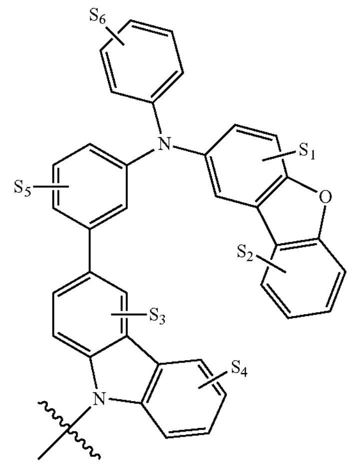
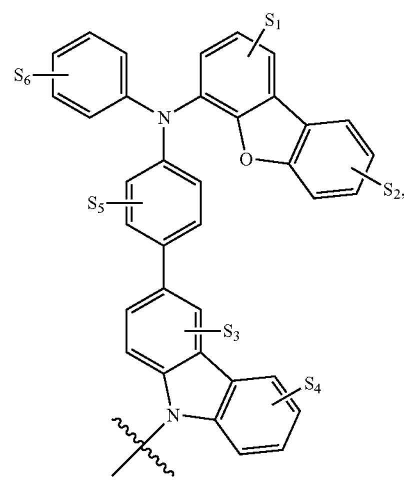
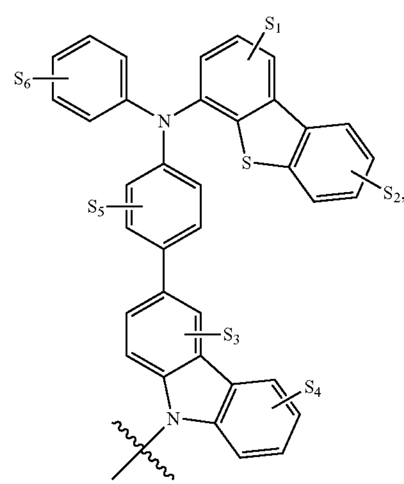
D31



D54



D55



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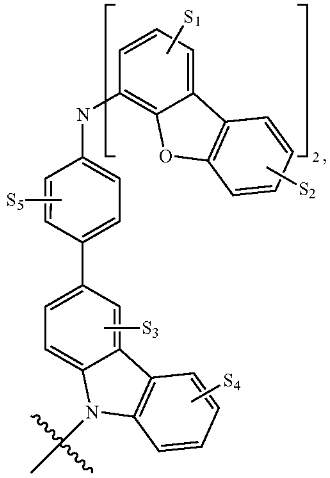
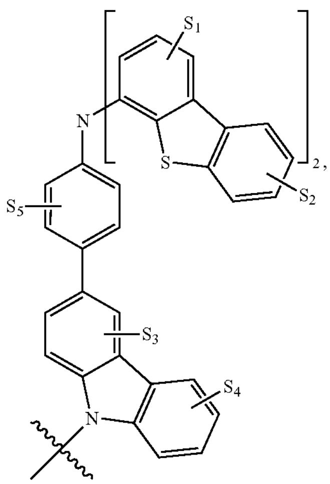
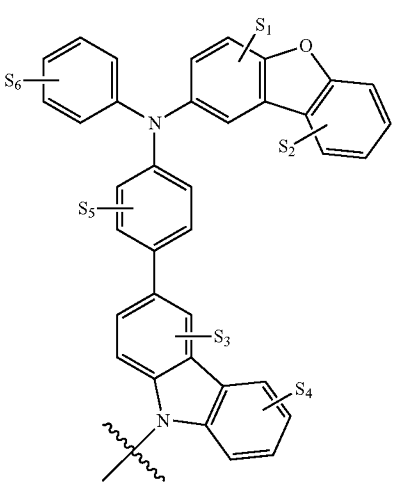
D56



D57



D58



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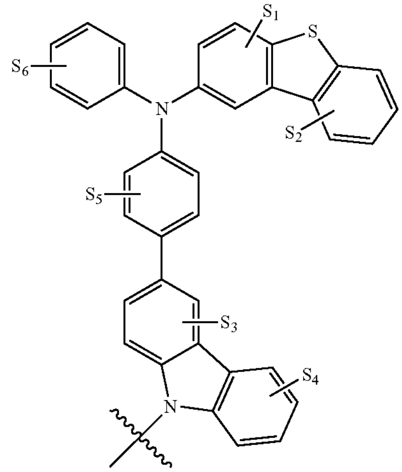
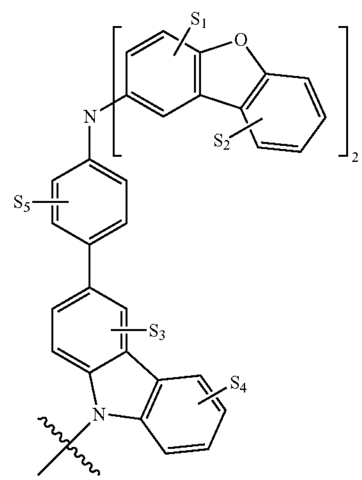
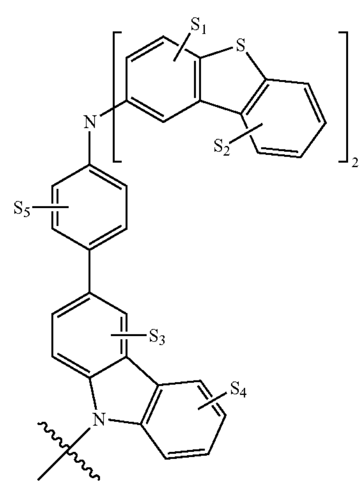
D59



D60



D61



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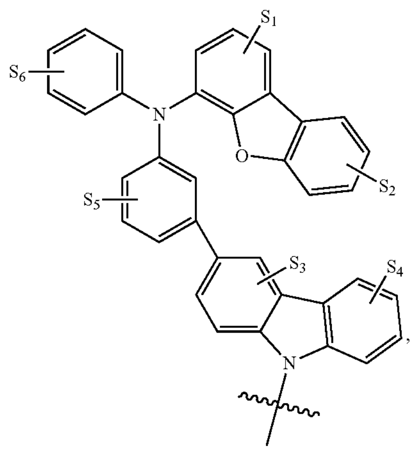
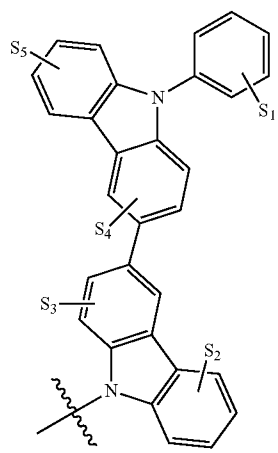


D70

, and



D144

wherein S_1 to S_6 represent mono, di, tri, tetra or penta substitutions with hydrogen, deuterium, halide, alkyl, cycloalkyl, heteroalkyl, arylalkyl, alkoxy, aryloxy, amino, silyl, alkenyl, cycloalkenyl, heteroalkenyl, alkynyl, aryl, heteroaryl, acyl, carbonyl, carboxylic acids, ester, nitrile, isonitrile, sulfanyl, sulfinyl, sulfonyl, phosphino, and combinations thereof.

11. The first device of claim **10**, wherein S_1 to S_6 are H.

12. The first device of claim **5**, wherein the first device emits a luminescent radiation at room temperature when a voltage is applied across the organic light emitting device;

wherein the luminescent radiation comprises a delayed fluorescence process.

13. The first device of claim **5**, wherein the emissive layer further comprises a first phosphorescent emitting material.

14. The first device of claim **13**, wherein the emissive layer further comprises a second phosphorescent emitting material.

15. The first device of claim **5**, wherein the emissive layer further comprises a host material.

16. The first device of claim **13**, wherein the first device emits a white light at room temperature when a voltage is applied across the organic light emitting device.

17. The first device of claim **16**, wherein the first emitting compound emits a blue light with a peak wavelength of about 400 nm to about 500 nm.

18. The first device of claim **16**, wherein the first emitting compound emits a yellow light with a peak wavelength of about 530 nm to about 580 nm.

19. The first device of claim **5**, wherein the first device comprises a second organic light emitting device;

wherein the second organic light emitting device is stacked on the first organic light emitting device.

20. The first device of claim **5**, wherein the first device is a consumer product.

21. The first device of claim **5**, wherein the first device is an organic light-emitting device.

22. The first device of claim **5**, wherein the first device is a lighting panel.

23. The first device of claim **5**, wherein at least one of the R comprises a donor group with at least two electron-donating nitrogens.

* * * * *